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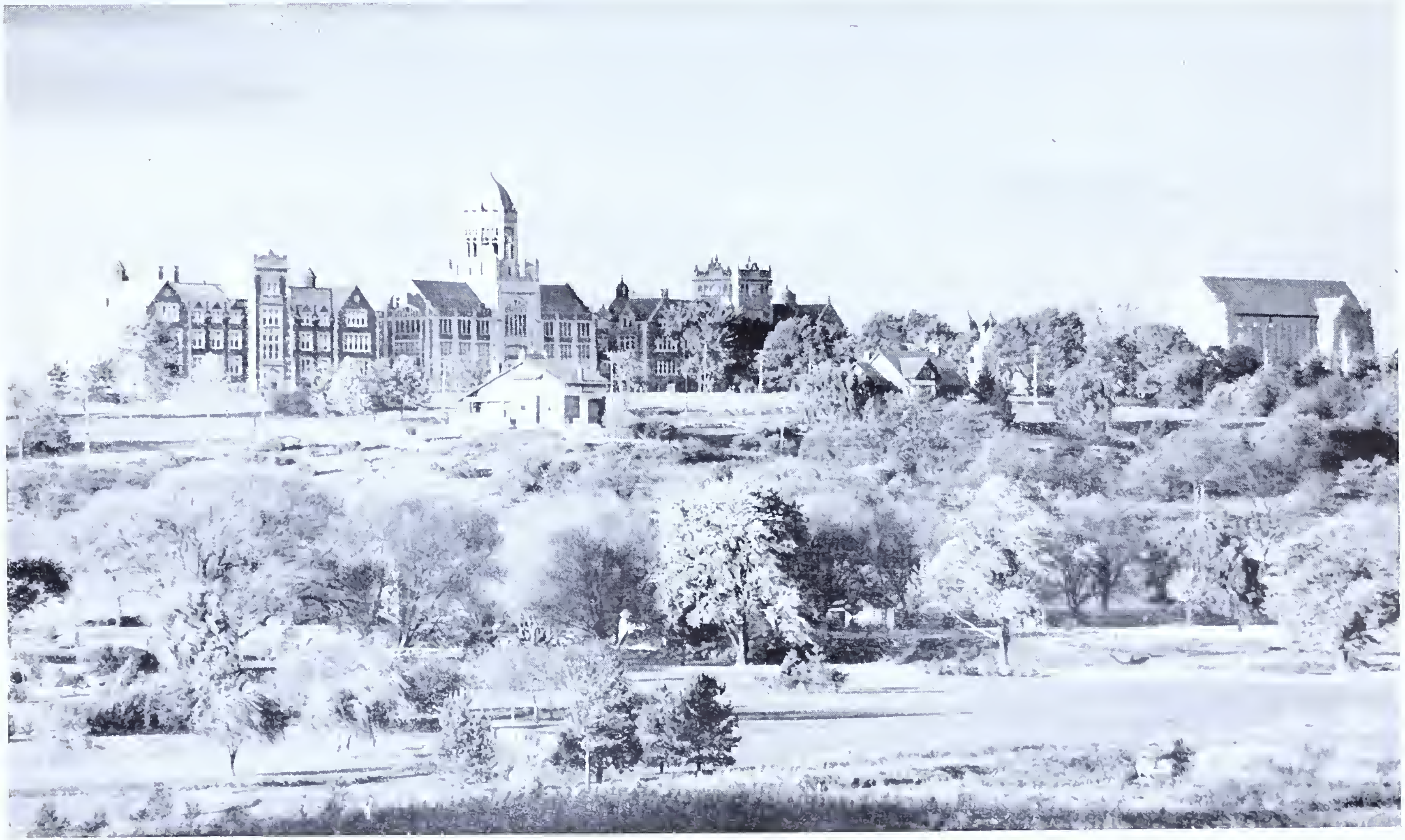

Muhlenberg College, Allentown, located on a typical hill of Allentown limestone. The hill rises about 100 feet above the channel of Cedar Creek. The college has a growing department of geology.

PENNSYLVANIA
GEOLOGICAL SURVEY
FOURTH SERIES
BULLETIN C 39

LEHIGH COUNTY PENNSYLVANIA

GEOLOGY AND GEOGRAPHY

BY BENJAMIN LEROY MILLER
Professor of Geology, Lehigh University

with chapters on

PRE-CAMBRIAN GEOLOGY

BY DONALD MCCOY FRASER
Associate Professor of Geology, Lehigh University

JACKSONBURG FORMATION

BY RALPH LEROY MILLER
Instructor in Geology, Columbia University

MARTINSBURG FORMATION

BY BRADFORD WILLARD
Professor of Geology, Lehigh University

TRIASSIC ROCKS

BY EDGAR T. WHERRY
Associate Professor of Botany, University of Pennsylvania

DEPARTMENT OF INTERNAL AFFAIRS
WILLIAM S. LIVENGOOD, JR., *Secretary*

TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, *State Geologist*

Harrisburg, Pa.
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Lehigh County, Pennsylvania

PENNSYLVANIA

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FOREWORD

Since September 1907, the senior author has held the position of Professor of Geology in Lehigh University. During this time his out-of-door laboratory has been the Lehigh Valley, particularly Lehigh and Northampton Counties. Alone, with his colleagues in the department, and with his students, all sections of these two counties have been visited and revisited. In addition many geographic and geologic problems and many bits of information have been brought to his attention by representatives of the various industrial organizations of the region. These have dealt particularly with problems concerning supplies of underground water, the utilization of the rocks of the area such as limestones for portland cement and lime, slates, sandstones, gneiss, sand and clay for structural purposes, weather and climatic conditions, and behavior of streams. As a result a great body of information has accumulated that supplements previously published data.

The author believes that an obligation exists to put the important part of this material into permanent form and to publish it in order that it may be available to a larger number of people. In fulfillment of this implied obligation, the present volume has been prepared. In its preparation, the writer has held in mind the interests of the general reader and of the students of the Lehigh Valley colleges.* So far as possible, technical terms have been avoided. The employment of technical nomenclature, such as every science has developed, permits shorter and more concentrated discussions, but tends to confuse those readers who are not primarily concerned with the particular science. The material included in this volume may have some interest to persons outside this region and unfamiliar with the local background but it is especially written for the residents of the Lehigh Valley and only incidentally for others.

The topics treated by no means constitute all the subjects that might be considered under the head of geography. A complete geography of the county should include many additional subjects, such as the plant and animal life, and the industrial development. It is profoundly hoped that persons competent to deal with other geographic factors may eventually likewise make available their accumulated information. Monastic learning and research in the natural sciences may afford much personal satisfaction to the investigator, but the results made available to the public may give much pleasure to a larger body of thinking people similarly inclined.

It must be recognized that much of this volume is the work of other investigators. As shown in the somewhat elaborate bibliography, scores of other persons have studied and reported on various phases of this work. For more than 200 years information has been accumulating. Some of these contributions are of little merit but many are otherwise and have been freely used. This work therefore represents the investigations of the past and present generations. To all these, but particularly to the writer's colleagues and former students, thanks are given. Since the writer's studies have extended over a period of one-third of a century, it is obviously impossible to recall and give credit to these individual contributions, much as he should like to do so.

---

* Muhlenberg College and Cedar Crest College in Allentown; Lehigh University, Moravian College and Theological Seminary, and Moravian College for Women in Bethlehem; and Lafayette College in Easton.

For assistance in the field, the writer particularly desires to thank his former students, J. Osborn Fuller, Philip B. Myers, Albert J. Getz, and Clayton L. Roloson.

It is a pleasure to acknowledge specifically the assistance freely given by the officials of the Lehigh Portland Cement Co., the Coplay Cement Manufacturing Co., the Giant Portland Cement Co., the Whitehall Cement Manufacturing Co., and the New Jersey Zinc Co. in supplying data concerning their operations and properties. Mr. M. B. Biery has kindly furnished records of many wells. The proprietors of the Call-Chronicle newspapers have supplied a number of excellent photographs for illustration. These and many others have made it possible to prepare this volume.

The collection of data and the preparation for publication has afforded much pleasure to the writer. If this report proves to be of interest or value to those for whom it is written, the writer will feel well repaid for his efforts.

BENJAMIN L. MILLER

Lehigh University,
Bethlehem, Pennsylvania,
April 18, 1941.

LEHIGH COUNTY, PENNSYLVANIA

INTRODUCTION

By Benjamin L. Miller

Lehigh County is in the eastern part of Pennsylvania. It is bordered on the north and east by Northampton County, on the southeast by Bucks County, on the southwest by Berks and Montgomery counties, and on the north and west by Schuylkill and Carbon counties. It lies between parallels 40°25′ and 40°47′ north latitude and meridians 75°20′ and 75°53′ west longitude, is irregular in shape, and has an area of 344 square miles. It includes portions of the following 15′ quadrangles of the U. S. Geological Survey: Allentown, Allentown West, Mauch Chunk, Hamburg, Boyertown and Quakertown.

The county possesses much of historical, industrial, and geological interest. Geologically its record goes back more than a billion years; in terms of human history it embodies probably a thousand years. In neither case can the time be given in exact figures. The geological record includes so many great earth changes that many of the phases or periods must be interpreted from imperfect data. Similarly, the story of the earliest human inhabitants in the region is vague, owing to the fact that the Indians preserved no written records. Even the activities of the earliest white inhabitants, who entered the region a little more than 200 years ago, are poorly known. Both human and geological records become increasingly more fragmentary and more difficult to decipher the farther back we go. Nevertheless, enough data remain for the specially trained individuals to unravel much of the ancient records.

OUTLINE OF GEOLOGICAL HISTORY

It is an interesting speculation to consider the happenings of the past billion years as designed to prepare the region for Man. Whether such an egotistical point of view is accepted or not, it is nevertheless true that the present human inhabitants are utilizing, and, in some cases, wasting the products of Nature that have been in process of formation for many millions of years, long before the appearance of Man on the earth.

The oldest rocks occur on South Mountain and the other irregular hills that constitute such prominent topographic features in the southern part of the county. They tell of a time when hot molten rocks forced their way to or near the surface from deep-seated reservoirs of magmas with prevailing temperatures above the melting points of ordinary rocks. These molten masses cooled and solidified as they proceeded upward, forming granites and other types of igneous rocks. Later, and perhaps several times, these first crystalline rocks were themselves invaded by other ascending masses of molten rock. These successive invasions and subsequent earth compressive and uplifting movements have modified the ancient rocks of the region until they are so complex as to make the deciphering of their history extremely difficult. Progress has been made but many problems are unsolved.

Most of the rocks now at the surface in Lehigh County are of sedimentary origin and were laid down as loose sediments—pebbles, sand, mud, and calcareous ooze—in a great inland sea that extended over the eastern States for several million years. Streams flowing from a great land mass, known as Appalachia, that lay to the southeast, brought these sediments, either in suspension or in solution, into this sea. Here they were deposited in beds aggregating several thousand feet in thickness. By the compressive force of overlying sediments, by lateral compression at different times, and also by the deposition of mineral matter by circulating underground waters, the pebbles have been compacted and consolidated to form conglomerates, the sands have become sandstones, the clays are shales or slates, and the calcareous oozes constitute the limestones. Over a part of the county there is a thin mantle of glacial débris, left by the melting of a great ice sheet that invaded the region during a recent geologic period.

These extensive sedimentary rocks were deposited in the sea in horizontal beds. At least twice since their accumulation they have been folded by intense compressive earth forces coming from the southeast. These movements threw the rocks into great longitudinal folds trending in a northeast-southwest direction.

The processes of degradation, grouped under the general term of erosion, have for ages been at work carving these rocks as the sculptor removes particles of rock to produce his work of art. We see in our existing hills and valleys the result of this erosion, which is still in progress.

On this background the later history of Lehigh County has been built. Without some knowledge of the past it is frequently difficult properly to interpret and evaluate some of the activities of the present.

CULTURE

Use.—With the exception of the most rugged portions of Kittatinny (Blue) Mountain and the South Mountains, all of Lehigh County is inhabited and the soil or underlying rocks have been utilized for the growing of crops, the mining or quarrying of useful mineral products, or for the sites of structures of various kinds. The cultivated portions of the county are used for growing wheat, corn, hay, oats, barley, and potatoes and for grazing. Dairying is an important industry. Proximity to the great commercial communities of New York and Philadelphia on one hand and to anthracite mines on the other, as well as excellent transportation facilities, have gradually developed the region more and more along industrial lines. A great variety of manufactured products originates in the numerous villages and cities. Machinery, cement, textiles, and scores of minor articles are produced in the region.

The higher and rougher mountains are too rocky to be cultivated, but they have furnished much timber to the residents. The best lumber, even in the early settlement of the region, came from the adjoining counties north of Kittatinny (Blue) Mountain, but the forests of the county did supply the settlers with logs and lumber, with fuel, and with charcoal for the iron furnaces. Even yet the forested portions of the county contribute to the welfare of the residents.

The more level portions of the county are most thickly settled. The population is naturally densest in the limestone valleys. Here are the principal towns and practically every foot of the area is capable of cultivation. The slate region, with steeper hills, has several small villages clustered about the slate quarries. Some of the hillsides are too steep for cultivation, but furnish pasturage or are covered with trees. The rougher portions of the county are more thinly populated, but there is practically no waste land. Here and there are residences on the slopes and tops of the steep hills and mountains, some of which are occupied during the entire year and others only during the summer. Some fairly steep slopes have been cultivated by the removal of the larger rocks of the hillside talus. With the exception of Kittatinny (Blue) Mountain, which forms the northern boundary, probably no place within the entire county is more than half a mile from a residence. Kittatinny (Blue) Mountain and the gneiss hills south of the Lehigh Valley are least used.

Population.—Complete statistics of population are difficult to obtain and may be misleading. The political units have changed so many times that inconsistencies are bound to appear unless full explanations show how county, township, borough and city boundaries have been altered from time to time. The following table shows some of the changes in population during the two centuries of occupancy by the white man. When Northampton County was organized in 1752 it is estimated that what now constitutes Lehigh County contained approximately 2,900 inhabitants:

Although the population of some townships has decreased at times, statistics show the gradual increase in population of the county. The slow growth of the township populations, which include those of the small unincorporated villages, and the relatively more rapid growth of the city and boroughs is striking. This is partly due to the extension of borough and city limits, but also indicates a definite trend from rural to urban conditions or generally from agricultural to manufacturing industries. Between 1890 and 1900 the city and borough population first exceeded that of the townships.

Highways.—Lehigh County is well provided with highways, thus rendering all parts readily accessible. In the early days there were several privately-owned turnpikes with toll houses and toll bridges. The turnpikes and most of the bridges have now been taken over by the State or local communities and freed. The improvement of the highways has been very rapid since the appearance of the automobile. Now a fine network of hard-surfaced roads, both concrete and macadam, penetrates all portions of the county. Many of the dirt roads have also been improved. The main highways are kept open during the winter by snow-plows and there is little interference even after the worst snow-storms. Sleighs, once used extensively, have almost completely disappeared.

In that portion of the county underlain by limestones the roads run in every direction and in most cases bear little relation to the streams and their valleys. In contrast, in the slate regions, where the irregularities of topography are more accentuated and the valleys narrow

Census of Lehigh County, 1790-1940

	Formed	1790	1800	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940
City																	
Allentown	1762	486	573	710	1,132	1,757	2,493	3,703	8,025	13,884	18,063	25,228	35,416	51,913	73,502	92,563	96,827
Boroughs																	
Alburtis	1913	----	----	----	----	----	----	----	----	----	----	----	----	----	795	823	885
Catasauqua	1852	----	----	----	----	----	----	----	1,653	2,853	3,065	3,704	3,963	5,250	4,714	4,851	4,746
Coopersburg	1879	----	----	----	----	----	----	----	----	----	392	454	556	683	870	1,057	1,193
Coplay	1869	----	----	----	----	----	----	----	----	728	774	880	1,581	2,670	2,845	3,279	3,109
Emmaus	1859	----	----	----	----	----	----	----	277	477	847	883	1,468	3,501	4,370	6,419	6,731
Fountain Hill	1892	----	----	----	----	----	----	----	----	----	----	----	1,214	1,388	2,339	4,568	4,804
Macungie	1857	----	----	----	----	----	----	----	410	486	701	644	692	772	768	842	856
Slatington	1864	----	----	----	----	----	----	----	----	1,508	1,634	2,716	3,773	4,454	4,014	4,134	4,062
S. Allentown	1909	----	----	----	----	----	----	----	----	----	----	----	----	1,814	2,549	----	----
W. Bethlehem	1880	----	----	----	----	----	----	----	----	----	1,414	2,759	3,465	4,472	9,389	11,129	----
									2,340	6,052	8,827	12,040	16,712	25,004	32,653	37,102	----
Townships																	Unofficial
Hanover	1798	----	736	850	866	1,102	1,478	1,762	2,380	2,804	3,813	2,863	3,324	3,907	3,329	429	455
Heidelberg	1752	965	1,238	1,433	1,900	2,238	2,308	1,589	1,369	1,441	1,567	1,437	1,411	1,238	1,049	1,061	1,071
Lowhill	1753	417	545	632	703	808	854	1,021	1,043	997	914	763	715	709	581	538	553
Lynn	1753	1,019	1,164	1,497	1,664	1,747	1,895	1,997	2,321	2,375	2,678	2,635	2,366	2,178	2,021	1,924	1,884
Macungie, L.	1743	1,263	1,844	2,420	2,802	3,323	2,156	3,036	3,438	3,661	3,952	3,657	2,920	2,893	2,226	2,605	2,683
Macungie, U.							1,769	1,562	1,761	3,061	3,023	2,511	2,081	2,609	2,450	2,675	2,964
Milford, L.	1738	1,151	1,617	2,033	2,416	2,829	3,081	1,236	1,448	1,505	1,563	1,424	1,233	1,089	1,107	1,050	1,248
Milford, U.								1,748	1,936	2,015	2,475	2,394	2,712	1,923	2,023	2,043	2,324
Salisbury	1753	1,007	638	933	1,165	1,342	1,488	1,884	2,216	2,860	3,078	4,100	4,582	2,828	4,201	5,564	3,560
Saucon, U.	1742	845	1,024	1,456	1,642	1,905	2,072	2,372	2,043	3,487	3,228	2,832	2,271	2,415	2,768	3,028	3,397
Washington	1847	----	----	----	----	----	----	1,862	2,047	2,464	2,517	2,668	3,096	3,477	2,870	2,738	----
Weisenberg	1753	615	755	1,046	1,175	1,285	1,427	1,726	1,823	1,644	1,627	1,514	1,366	1,222	1,139	1,168	1,167
Whitehall	1753	1,253	2,032	2,551	----	----	----	----	----	3,318	3,929	5,514	7,935	9,350	9,886	10,707	10,263
Whitehall, N.	1810	----	----	----	1,807	2,008	2,234	2,946	3,575	4,170	3,245	2,847	3,280	3,580	3,325	3,966	4,112
Whitehall, S.	1810	----	----	----	1,623	1,952	2,290	2,913	4,085	2,748	2,884	2,204	2,472	2,497	2,971	3,732	4,290
	----	----	11,593	14,851	17,763	20,499	23,294	28,776	33,388	36,860	39,079	39,363	41,765	41,915	41,946	43,228	----
Lehigh County	1812	8,535	12,166	15,561	18,895	22,256	25,787	32,479	43,753	56,796	65,969	76,631	93,893	118,832	148,101	172,893	177,395

and steep-sided, the roads are along the streams and on the stream divides. As the drainage here is along north-south lines, the roads are prevailingly in the same direction.

The roads in the southern part of the county, where the crystalline rocks are predominant and the hills are of irregular shape, have a less pronounced pattern, although they tend to follow the valleys.

Few roads cross Kittatinny (Blue) Mountain on the northern boundary. Lehigh Gap affords easy passage, but the only highway there is on the Northampton County side.

Railroads, trolleys and canals.—The county has an adequate railroad system connecting all parts. The Reading Railway System has several lines, the Lehigh Valley Railroad, and the Central Railroad of New Jersey follow the Lehigh River from Bethlehem to the Lehigh Gap and beyond.

The extensive railroad system of the county is largely due to the important slate and cement deposits and to the location of the region with reference to Philadelphia and New York in one direction and to the anthracite fields, western New York and central and western Pennsylvania in the other direction. In turn, it may be said that the industrial development of the county is largely due to the fine transportation facilities.

Until recently there were several interurban trolley lines between the principal towns of the county and adjoining regions. Some of these have now been replaced by bus lines and most of the tracks torn up. The trolley lines between Allentown and Philadelphia and between Allentown and Easton still remain.

A canal owned by the Lehigh Coal & Navigation Company follows the Lehigh River from Mauch Chunk to Easton and thence southward along the Delaware River to Philadelphia. Several dams were built to divert river water into the canal, and locks were constructed at these places. These are conspicuous at Allentown and Bethlehem. This canal was built in 1824 and was long used for the transportation of anthracite to Philadelphia and to towns along the route. For several seasons past no canal boats have been in operation and the principal use of the canal is as a source of water power in a few places.

EARLY HISTORICAL DEVELOPMENT

By Benjamin L. Miller

The human history of almost every region, as one follows it backwards through time, passes into vague and indefinite trails where facts and legends intermingle in inextricable confusion. It is the purpose of the historian to pick his way through this maze of endless contradictions and sift the chaff from the grain. Even where written records are available their fragmentary character often prevents positive conclusions. When the historical research concerns peoples who have left no written records, only some of their handiwork, the difficulty increases. The early history of Lehigh County embodies many such problems.

A discussion of the history of any region in Pennsylvania must be concerned with both the early Indian inhabitants and their successors, the white men. The writer is inclined to introduce the question of still earlier habitation as this has long been in his mind, and particularly so since there opportunely comes to his desk, as he now writes, a publication * pertinent to this topic.

Pre-Indian Occupation

A vast literature deals with early Man, and almost every European museum contains extensive collections of artifacts left by earlier civilizations. Various classifications have been proposed for the different stages in Man's development as evidenced by these discoveries. Generally three major divisions have been made—Eolithic, Paleolithic, and Neolithic—but with numerous minor subdivisions. The question has frequently been asked, especially by European geologists and anthropologists, as to why similar evidence of early Man has not been obtained in North America. Was the North American Indian the first man to occupy this continent? This question has been debated for almost a century and at times so heatedly that one prominent geologist is reported to have given the advice to his subordinate workers to destroy promptly any artifact they might find that did not present definite indication of its relatively recent origin, and thus avoid unseemly and prolonged controversy. Nevertheless, the evidences of Man having lived in North America previous to or during the Ice Age have accumulated by finds in many States. These artifacts have been found in association with the remains of animals now extinct here, such as the mastodon, sloth, armadillo, glyptodont, bison, camel, tapir, sabre-tooth tiger. Pennsylvania is not one of the States listed by Sellards where such finds have been reported, but New York, New Jersey, Delaware, and Ohio are included. Doubtless many heralded reports of artifacts of ancient Man should be ignored as of little value, but many cannot thus be lightly dismissed.

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* Sellards, E. H., Early Man in America; Index to localities, and selected bibliography: Geol. Soc. America Bull., vol. 51, pp. 373-432. New York, 1940.

The writer firmly believes that human beings wandered through these sections previous to the period when the North American Indian is supposed to have made his appearance. Whether these were the direct ancestors of the Indian or belonged to a distinct race that was exterminated is a moot point. It also seems plausible that some of the artifacts found in this region and attributed to the Indian were actually the work of much more ancient man. The fact that the Indian was still in the Stone Age culture when America was discovered may have led to this confusion. Some anthropologists are inclined to ascribe some of the stone artifacts so plentifully found in this region to an earlier, more primitive civilization. The whole question is an open one and existing data do not warrant dogmatic statements either *pro* or *con*. The matter is mentioned here solely for the purpose of suggesting that future observers may keep the problem in mind and be on the outlook for evidence.

In this connection a quotation from an article by A. F. Berlin, who was one of the most active anthropological investigators of the region, is pertinent. He found on Jeter (then called Lehigh) Island great numbers of artifacts. Of these he attributed nearly all to the North American Indian, but among them he found some that he regarded as older and properly classed as "Paleoliths."

> "*Palæoliths.*—It will be proper to mention here first those rude objects of stone, which in the past have created and at the present time are causing so much attention. I succeeded after careful search in picking up, at different times from the surface eight of these implements, nor was I fortunate in obtaining any where the sand-diggers worked. I also watched carefully at the sand-wash but found none there. I infer from this that they are very rare on this island. Six of the objects found were made of quartzite, the seventh of yellow jasper. All represent the forms of the river-drift implements from England and France, as well as those discovered by Dr. C. C. Abbott in the gravel at Trenton. . . . Although rudely made, secondary chipping is shown plainly along the edges, from which one is compelled to infer that they were finished implements." (p. 13.) *

Indian Occupation

The region now embraced in Lehigh County, when first visited by white men, was sparsely occupied by the Lenni-Lenape (usually shortened to Lenape) or Delaware Indians, a branch of the Algonkians. According to their traditions they came from the west. This idea is in accord with the prevailing belief that the American Indian is of Mongolian ancestry and entered the continent by way of Bering Strait. From thence over a long period of years they spread throughout North, Central, and South America.

The Lenape Indians were divided into three tribes, two of which shared this area, with the limits of their respective claims indefinite. The southern division, the Unami, whose totem was the turtle and accordingly known as the Turtle Tribe, claimed the territory from what is now northern Delaware to the Lehigh River, or according to other beliefs to Kittatinny (Blue) Mountain. The Minsi tribe, with the wolf as their totem, occupied the headwaters of the Delaware and Lehigh rivers.

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* Berlin, A. F., Lehigh Island and Its Relics: The Archaeologist, vol. 1, pp. 13-16, January 1893, Waterloo, Indiana. (Library of Historical Society of Pennsylvania.)

It seems fairly certain that the Iroquois Indians pushed into Pennsylvania before the tenth century and gradually supplanted the authority of the Algonkians over much of that territory. When the European settlers appeared in eastern Pennsylvania the Lenape or Delawares had come under the domination of the Iroquois, some tribes of which had banded together to constitute the Five Nations. The Iroquois applied the title of Women to the Lenape, a term which in time became very obnoxious, as indicating weakness and inferiority.

The territory now comprising Lehigh County probably was used by the Indians almost exclusively as hunting and fishing grounds, although for these purposes less valuable than the regions north of Kittatinny (Blue) Mountain. The entire area was covered with several varieties of oak, maple and other deciduous trees, with few conifers. Large trees were rare and grew only along the streams, a condition probably brought about by the occasional forest fires set by the Indians to drive the game through the gaps in Kittatinny (Blue) Mountain for slaughter by the hunters stationed there in ambush.

Lehigh County is fortunate in having had several able investigators of Indian life and lore as residents of the county or nearby counties. From their writings one can obtain a fairly comprehensive view. A list of the more important is included in the bibliography at the close of this chapter. The best account of the Indians of this section is that by Alfred Franklin Berlin (Chapter III, pp. 18-40, History of Lehigh County by Roberts, Stoudt, Krick and Dietrich, 1914). Mr. Berlin has * furnished fine descriptions of many of the artifacts found in this district—pottery, net-sinkers, hammers, grooved and ungrooved axes, adzes, knives, scrapers, gorgets, ceremonial weapons, pestles, spear-heads, drills, and arrow-heads.

It seems that there were no permanent Indian villages in what is now Lehigh County. One Indian chief, Kolapechna (from whose name Coplay has been derived), lived for several years along what is now Coplay Creek near the present location of Neffs. From the great number of artifacts and jasper chips found on Jeter Island and on the flat land on the south side of Lehigh River within the broad curve of that stream between Allentown and Bethlehem (commonly known as the Geissinger Farm) it would seem as though groups lived in those places repeatedly, if not continuously. Trout Creek near its junction with the Lehigh River was another favorite place for the Indians to tarry. Temporary villages also probably existed in the vicinity of the jasper quarries described on later pages. Various places in Weisenberg, Upper Milford, and Upper Saucon townships have been thought to be the sites of Indian settlements because of the abundance of artifacts.

A settlement of converted Indians under the supervision of the Moravians was maintained on the outskirts of Bethlehem between 1758 and 1763. The village was named Nain by Count Zinzendorf in 1742 when the idea of a Christian Indian village was first considered. The village was in Hanover Township a short distance north of Union Boulevard, West Bethlehem. When the Government moved the Indians to Philadelphia all the houses were destroyed but one, which

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* Berlin, A. F., op. cit.

was moved and now stands on Heckewelder Street, Bethlehem, a short distance from the Central Moravian Church.

The Indians ranged all through the county and their arrow-points and other stone articles have been picked up everywhere. They hunted in the forests, fished in the streams and probably locally cultivated some of the ground. They were never numerous and appear to have moved about frequently. The best hunting grounds lay to the north of Blue Mountain and some of their more permanent settlements were farther south in what is now Bucks County.

The Delaware Indians were generally friendly, but became incensed when the infamous Walking Purchase fraud deprived them of a large part of the land which they had long claimed. Since the whole of Hanover Township and, by implication, considerably more of Lehigh County was taken from the Indians by this transaction, a brief sketch of the transaction is given.

William Penn on his arrival in this country took the position that the land did not belong to him, regardless of the fact that he had been given a charter by Charles II on March 4, 1681, to a large tract of land "lying north of Maryland; on the east bounded by Delaware river; on the west limited as Maryland; and northward, to extend as far as plantable." He, therefore, from the first purchased from the Indians the lands which he desired and by so doing won and retained their friendship. This policy was continued by his successors, although his son Thomas, who, with his brother John, succeeded to the titles of the American holdings on the death of their father, was not highly regarded. His honesty was questioned in different transactions and especially when a few years before 1737, the Proprietaries' agents produced a document bearing the endorsement "Copy of the last Indian purchase." This was claimed to be a true copy of a deed made August 30, 1686, and signed by three Delaware Indian chiefs by which William Penn was given a tract of land north of the "Neshaminy Purchase" extending from its northern boundary as far as a man can walk in a day and a half and thence eastward to the Delaware River. This was shown to the Indians in 1737 and reluctantly accepted by them as genuine, although they had no previous knowledge of its existence and all the signatories were dead. The common belief is that the entire instrument was a forgery or an altered copy.

At sunrise on the morning of September 19, 1737, three trained walkers started from a place near Wrightstown, Bucks County. They walked until sundown and resumed the next morning. At noon they had walked about sixty-seven miles, to a point a few miles east of Lehighton. A line later surveyed to the Delaware River gave the Proprietaries a large part of Carbon, Monroe, and Lehigh counties, as well as all of Northampton County. The walkers probably spent the night near an Indian village on Hokendauqua Creek just east of the present borough of Northampton, although some claim that they passed Blue Mountain before the end of the first day and slept in the woods near an Indian village called Meniolagomeka in the valley of Aquashicola Creek. The route is also in doubt, but it seems that they crossed the Lehigh River just below the present site of Bethlehem and proceeded northwest across Monocacy Creek, passing near the sites of Northampton and Walnutport. Most writers state that the walkers passed through Lehigh Gap, but others claim that the trail followed passed over Blue Mountain through Smith Gap. Although the records disagree, the writer is convinced that the route was through the Lehigh Gap.

Regardless of whether the purported deed of 1686 was genuine or not, the Indians felt that they had been cheated in that the area covered in the walk was excessive and far greater than intended. One Indian expressed his indignation by saying that the walkers ''no sit down to smoke, no shoot a squirrel, but lun, lun, lun all day long.'' Accordingly, the Indians resented the amount of territory covered and refused to vacate the region. However, by 1742 all of the Indians with the exception of a few individuals, who were granted the privilege to remain, had removed from the confines of the area claimed. This was accomplished with the assistance of the Iroquois Indians, who lived to the north and who had long assumed an oppressive dominance over the Delawares.

The Indians deprived of their lands found their new habitations gradually encroached upon. A harboring resentment finally broke when the invincibility of the whites was shown no longer to exist by the defeat of Braddock's army in 1755 by the Indians and some French. The Indians had continued to wander back and forth through the regions they had once possessed and now seemed to conceive the idea that they could redress the wrongs they had suffered and reclaim the lost territory. For several years the isolated settlers in the northern portion of the county were harassed by occasional raids. Several persons were murdered and scalped and property destroyed. This called for the erection of a series of forts along the Blue Mountain between the Susquehanna and Delaware rivers. Those located in Lehigh County as described in ''Frontier Forts of Pennsylvania'' are worthy of brief mention.

> *Fort Everett.* "It stood in what is now a level, ploughed field, about ¼ mile north of Lynnport, Lynn Township, Lehigh County, distant about 150 feet from the house of M. K. Henry, a tenant of Mrs. David Stein, to the East, and about 250 feet from the creek to the west, which flows past the Slate works and empties into Ontelaunee Creek. A spring, but a few feet south of where the fort was erected, marks the position of what was then a well of water. It was a blockhouse, about 25 ft. x 30 ft. It stood on the property of John Everett, a man of prominence at the time, and of the same family as Edw. Everett, of Massachusetts, whence he came. Whether, however, the building was the house of Mr. Everett, or whether the fort was a separate building erected on his place, it is difficult to say. From what I could learn I am inclined to believe that it was a separate building, erected as a house of refuge and defense, consisting of a log house surrounded by the regulation stockade. In that case we may very properly fix upon the beginning of 1756 as the time of its birth." (See bibliography, Richards, 1896, p. 148.)

It appears that at times as many as 44 soldiers were stationed at the fort. Guns, ammunition, and several months' provisions were stored there. All this seemed necessary, as the Indians made frequent raids in the region and murdered and scalped a number of people, besides carrying others into captivity.

''Fort South of Lehigh Gap.''—In the records the location of this fort is somewhat indefinite. As a member of the Commission to locate

the Frontier Forts, Henry M. M. Richards made a careful investigation and decided that this fort was located along Trout Creek at what was known as Trucker's or Kern's Mill (Plate 4A) "some 175 feet north of the bridge at Main St.," Slatington. The place seems to have been fortified and at times as many as 12 soldiers were stationed there. It has also been called Kern's Fort and Dry Fort.

Deshler's Fort.—Adam Deshler lived close to Coplay Creek between Egypt and Coplay. His home has been called a fort and was probably a place of refuge in times of danger, although there seems to be no record of soldiers ever having been stationed there. A wooden structure erected nearby may have quartered soldiers for a time during the Indian uprising in 1763.

The most serious Indian disturbances occurred in 1755, 1756, 1757 and in 1763. After that the Indians moved farther away and the white inhabitants of Lehigh County were left free to develop the region.

Indian Jasper Quarries in Lehigh County

The Indians built no permanent structures and they made only minor use of the soil. Their chief occupations of hunting and fishing did not modify the country. They did, however, discover what to them were valuable deposits of jasper on the slopes of the high hills in the southern part of the county, and these they worked extensively. The chief investigations of the old workings there were made by Henry C. Mercer in 1891 and 1892. In view of the general interest in the subject, his principal contribution, not readily accessible to most persons, is reproduced in its entirety. In part it concerns some places beyond the confines of Lehigh County and in some respects his geological interpretations have since been modified, yet it still remains the most important discussion of the utilization of the jasper of the region by the Indians.

Besides jasper the Indians undoubtedly picked up pieces of black flint, chalcedony, and quartz from which they made arrow-heads, knives, axes, and ornaments. These minerals are so widespread that one cannot identify their source. The jasper, however, is so distinctive that it can fairly reliably be attributed to the quarries of this region, even though the objects made from it are found in distant places. The abundance of jasper chips found on Jeter Island, on the Geissinger Farm (the low ground in the bend of the Lehigh River between Allentown and Bethlehem), and elsewhere plainly indicate that in general only the rough trimming was done at the quarries and the finishing was done in the camps along the river.

INDIAN JASPER MINES IN THE LEHIGH HILLS*

By H. C. Mercer

Expeditions sent out by the University of Pennsylvania in the summers of 1891 and 1892 discovered or explored nine ancient jasper quarries in Bucks, Lehigh, and Berks counties, Pennsylvania. The outcrops of the well-known Indian blade material occurred generally in connection with veins of hematite and followed the trend of the Lehigh hills from the Delaware almost to the Schuylkill. Messrs. Charles Laubach and J. A. Ruth, of Riegelsville, had known the nine flake-strewn pits on Rattlesnake hill, about a mile from the Delaware, for several years, and the former called our attention to them in 1891.

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* The American Anthropologist, vol. VII, 1894, pp. 80-92.

The twenty pits at Saucon creek (Wieder farm, two miles west of Limeport, Lehigh county, Pennsylvania) were discovered by Mr. Laubach and myself in 1891, on following the clue of a farmer who described the dump-heaps as "Indian mounds." I discovered the ten diggings on the Mast farm, a mile and a half south of Limeport, in 1891. The existence of the sixty hollows at Vera Cruz, Lehigh county, Pennsylvania, had been suspected by Mr. A. F. Berlin, of Allentown, and his suggestion led me to them in 1892, to the one hundred and thirty-eight at and about the C. C. Miller farm, at Macungie (Lehigh county, Pennsylvania), on September 20, 1892, and to the five at Feuersteinberg (near Bowers station, Berks county, Pennsylvania) shortly after. I discovered the two pits at Coopersburg (Bucks county, Pennsylvania) and the twenty at Leinbach's mills (Berks county, Pennsylvania) in 1892.

All the diggings, except those at Saucon creek, Coopersburg, and Long Swamp, are at ill-watered and rather uninhabitable sites. The pits, save the larger ones at Vera Cruz and Macungie, are small in comparison with the Flint Ridge (Ohio) workings, while the chips, where cultivation reveals them, are coarse and the material comparatively intractable. "Turtlebacks" are very rare in comparison with the numbers found at Flint ridge and at Piney branch (District of Columbia).

At Saucon creek some arrow-head workshops and a small mound in a neighboring swamp yet remain to be fully explored, but Macungie, explored in September and October, 1892, with its 108 pits and its half-wooded area of about six acres, will serve as a type of all the quarries.

The Possibility of Sink-holes

Where there is jasper there is limestone, and where limestone, sink-holes. We were on the north slope of the Lehigh hills and hence overlooking the valley which, margined west by the Alleghenies and east by highlands variously named, stretches from New York to Alabama.

Rain-water, with its carbonic acid trickling through the jasper-bearing, clay-bedded magnesian limestone under our feet, had made caves, and their roofs had fallen in, so there were sink-holes in the neighborhood. Four small depressions of the surface, like large woodchuck holes among the tree roots, at the southwest corner of the quarries, lacking dump-heaps, looked like sink-holes, so that there seemed a chance that men had not dug the 108 holes outright, but had scratched upon the slopes of natural funnels against already-denuded jasper layers. But eight shafts sunk here and there in the pit margins through disturbed soil, charcoal, and refuse, sometimes reaching the undisturbed stratum of forest mould (as at shafts 4, 6, 10, and 11); and sometimes not getting below the disturbance (as at 7, 5, 13, and 9), satisfied us that the margins were not level as at the sink-holes but artificially piled-up heaps.

The shallowest dumps are at shafts 6 (3 feet) and 10 (2 feet 4 inches). Then comes 11 (4 feet 3 inches) and 4 (6 feet 4 inches), while at 5 there is no bottom at 8 feet 4 inches; none at 7 at 6 feet 4 inches; none at 3, at 7 feet; at 8, at 4 feet 4 inches, or at 9 at 5 feet. The small trenches 4½ and 6½ at distances of 60 and 30 feet from the pit margins showing no disturbance prove that the dumps did not extend so far. Moreover, a glance at the sectional drawings, taken from shaft 11 to shaft 5 demonstrates that in two cases, which fairly represent the measured instances, the cubic contents of the dumps equaled that of the holes; and we had done enough to prove that if we could have planed down the dumps to the original surface line the pits would have been about level. The depressions were therefore not sink-holes, but had been dug by men.

An Unsuspected Excavation

But, as observed before, there were four small real sinkings, and the only way to explain them, and Mr. Miller's statement that they had caved down in the last ten years, and that plow-horses had become entangled in similar ones in the next field, was to follow down the deepest of them, 2 feet in diameter, 3 feet deep, and extending sidewise under the roots. Our shaft 12 showed that for 14 feet down at this sink, and continuing 11 feet below its bottom, the yellow soil containing charcoal and chips has been disturbed. At 8 feet we encountered a limestone ledge and followed the traces of ancient work downward over its edge until at 14 feet these seemed to slope away diagonally out of reach of our shaft. If we are to believe James Garr, who stated that he sunk a pit in another sink about 30 feet farther to the west and found traces of disturbance to a depth of 40 feet, when he struck the limestone ledge above mentioned, we had worked into an Indian digging about 40 feet in depth and probably 100 feet in diameter that had been completely filled up by the ancient workmen.

But, without using Garr's testimony and refraining from speculation as to the real size of the pit, it is certain that the sink had fallen and we had worked through level ground already dug to an unknown depth, and whether the sink testified to a cave somewhere in the limestone below or a cavity left by the Indians as they piled in the transported earth, it told us certainly more than we bargained for and detracted nothing from the magnitude of the ancient labor.

The Diggings the Work of Indians

Having settled that the pits are artificial; that notwithstanding the limestone in the neighborhood it is not reasonable to suppose that any of them could have been in part or wholly sink-holes (since every depression has its dump and the dumps are about sufficient to level the whole area); that inferably all of the pits had been more or less filled in with excavated earth by the quarrymen; that an area now level had been worked to a depth of 14 feet at least, and that finally it may be safe to say that double the work has been done suggested by the appearance of the surface, it remains to ask when and how were the pits dug and who dug them?

An old stump with 195 rings, on the side of a pit at Vera Cruz, and a tree nearly four feet in diameter cut down by Mr. C. C. Miller at Macungie in the bottom of a depression, would put back the abandonment of work in these two shafts to about 1680-'90; and that all are the work of Indians is proved by (a) two fragments of polished celts and one perfect and three broken arrowheads found by me on the edges of the diggings; (b) several small thinned-down blades found near the pits; (c) an arrowhead factory, where I found two fragments of finished arrowheads in the refuse, situated near a brook about three-eighths of a mile from the jasper outcrop; and lastly (d) by the fact that the material found and worked in the pits is jasper, a stone in continual use by early Indians, and worked fragments of which strew every village site in the Delaware valley.

The Method of Excavation

Admitting, then, that no mysterious or unknown race made the pits, vast as the work is, but the Indian, once supposed incapable of sustained labor, the Red man of the grooved stone axe, polished celt, banner stone, and gorget, as encountered by Campanius and Kalm, the next question is, how was the labor accomplished?

This can be answered to some extent, but not fully, by a study of shaft 2, sunk down to the undisturbed bottom of one of the pits (see Fig. 1). Lying on the unworked clay, at a depth of 18½ feet, was a large disc-shaped implement of chipped limestone a foot in diameter and well worn on its cutting edge.* At the fourteenth foot, among the refuse, a smaller tool, similarly worn, of quartzite and a rude point (of limestone) were found. While at the bottom again two cavities in the clay produced, on running in plaster of paris, the facsimiles of two sharpened wooden billets (long since rotted away and leaving only their moulds), one about 6 inches in diameter and of unknown length, as the upper part was destroyed in digging, the other with a diameter of about 2 inches and 2½ to 3 feet long.

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* I regret that I have been unable to publish illustrations of this and the other interesting stone specimens found in shaft 2; also drawings of the oven there discovered, and of the arrangement of layers in shaft 12.

It is needless to go into details as to bark, twigs, slight charring at the ends, etc. The unique specimens now at the University of Pennsylvania's museum of American archeology speak for themselves. Granted that the Indian quarryman used copper tools not yet found, or pick-axes of deer antlers like the ancient flint-workers of Brandon, in England, can we suppose that he did not employ poles of various sizes charred, and sharpened like these with stone tools, both to scratch and delve the ground and pry up the bowlders? And so, whatever we say of the quartzite implement at the fourteenth foot, shall we doubt that the ponderous chipped disc, showing unmistakable marks of usage, was handled as a digging tool in the fine yellow clay on which we found it?

The ocherous clay, or decomposed diorite interbedded with the limestone, at Macungie, is often highly tinted with yellow, that at Vera Cruz is sometimes red, pink, and bluish. Manganese is abundant at both places, besides a talcose slate that cuts easily, when freshly dug, into pipes and amulets; but as yet we have no proof that the excavations were made or altered for any of these substances. Thus far the study of the quarries proves that jasper was the material sought, and the questions remain: In what state did the Indian find it? How did he take it from the earth, and how reduce it to his desired shape?

A shaft of the Durham Iron Company encountered a solid vein of red jasper under the Indian jasper quarries, at Rattlesnake Hill, at a depth of about 100 feet, and at Macungie Mr. James Garr says that he reached a solid yellow ledge of it in his shaft, sunk for curiosity, in one of the pits at 30 feet beneath the surface. But our shaft, since it did not reach the undisturbed edges of the old hole, did not determine that no ledge existed, though it did prove that nodules were frequent. These are found on the surface, varying in diameter from 2 inches to 4 feet, at all the diggings; and one, with its thick, silicious coat, about 3 inches in diameter, was excavated at a depth of 19 feet from the undisturbed clay at the bottom of our largest shaft. Sometimes partly chipped, sometimes untouched, these nodules are found scattered everywhere in the dumps.

Yet as they, and the chips and splinters that accompany them, here bear only a proportion of about 10 per cent to the clay and are pretty evenly distributed through the mass, it is evident that the pits were to no great extent worked out of a solid ledge. If they had been, the constitution of the dumps would have betrayed it. We should have found more stone than clay in them. But we always found less, and very much less.

The evidence thus far indicates that after rolling away the surface nodules those lying deeper were pried up one by one with sharpened poles and the surrounding clay scraped away until the pits were made.

Traces of Fire

Scattered fragments of charcoal were scarce in shaft 12 below the ninth foot, but all the other diggings and dumps were sprinkled thick with bits of charcoal. About 20 per cent of the chips and 10 per cent of the large blocks were reddened as if by fire, while reddened fragments were abundant in all the fire-places. Nothing was surer than that fire had played a great part in the quarrying process; but while four fire-places examined showed no trace of cooking, they also gave no sure clue to their purpose, and there would have remained a doubt whether the fires had not been built for warmth had not a fifth hearth discovered in shaft 2, at a depth of 15 feet, seemed to settle the question. It was an oven regularly built of blocks of jasper and contained a mass of charcoal and ashes (see Pl. 1). The fact that the sides of the blocks were reddened, and several had already split through the middle, while the interstices were filled with fine splinters, offered conclusive evidence that the quarrymen had built the fire to fracture the blocks, which measured 2 feet, 1½ feet, 6 and 7 inches, respectively, in diameter.

My experiments proved (a) that if a large block of 2 feet in diameter is thoroughly heated on a wood fire it breaks into numerous pieces at a moderate blow; (b) that only the fragments near the fire are reddened; (c) that the fragments lose their original gloss by the process. The luster, however, seemed to be regained by long burial in damp clay, as was indicated by the high-polished fracture of some of the reddened chips found on the fire-places. Moreover, many of the worked forms gathered on the surface had been probably fire-reddened, and it is not unlikely that the Indian could have so heated the blocks as to reach their purer parts without spoiling the whole, while many of the large and coarse blocks might have been fire-fractured to get them out of the way.

The Transport of Jasper from the Quarry

Lastly, what was done to the jasper after excavation? This brings us to the chips and refuse found in the shafts and on the surface. (1) In the large shaft 2, two leaf-shaped forms of jasper ("turtlebacks") were found at the eleventh and two were found at the sixteenth foot, none of them showing signs of use on their cutting edges. In shaft 5 and 7 I found hammerstones at the first foot, in shaft 12 another at the fourteenth foot, and in the fields close to the pits 253 leaf-shaped forms and 55 hammer-stones. Certainly 70 per cent of the hammer-stones were broken, a very few were made of sandstone, about 10 per cent were of jasper, but most consisted of quartzite, or its equivalent, metamorphosed Potsdam sandstone, pebbles no doubt found in the beds of neighboring streams or where on hillsides marine forces had rolled them since Laurentian times. Many of them were well battered and many so reduced by successive blows following one plane of their circumference as to have the characteristic appearance of heavy discs, while it is important to note that none of them, with two or three doubtful exceptions, are pitted on the sides.

The refuse may be divided into four classes:

(a.) Chips and fragments of no inferable design.

(b.) Rough leaf-shaped forms not betraying their artificiality in their fractures, but only in their comparatively great numbers. Had the Indian been pounding on argillite pebbles, the blows would have left their mark in a series of conchoidal fractures, and, as in the quartzite specimens from Piney branch, the marred pebble surface would have told the tale. But here the cross-grained jagged edges often explain little, and it is only after we have visited other jasper outcrops where no such fragments as these exist and convinced ourselves that frost does not even account for the chips, much less for the hammer-stones, in a word, after we have gathered these specimens by the dozen, thrown them away and picked them up again, that we are finally convinced, in spite of the criticisms of friends, that nearly as many blows have been expended upon them as upon the ordinary "turtleback," and that it is only the coarseness of the material that hides from us in these ruder instances the handiwork of man.

(c.) The "turtlebacks." About these there is no doubt. We need no context to settle their artificiality; each, big or little, vouches for itself, as do the similar forms in argillite and sandstone from the Delaware or Susquehanna beaches. Standing in a ratio of about 1 to 15 of the former class, they are not nearly as common as at Flint ridge and Piney branch. To gather the 153 that we found on six or seven occasions, varying from 1 to 5 inches in length, required careful, painstaking search; still they were there, and it is the question of their purpose that concerns us most. The Indian made them, either as finished or unfinished implements, for they

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may not be assigned to chance or symbolic use. We cannot, however, here use the argument that their mere presence proves their intentional abandonment, for, being as scarce as arrow-heads in an "Indian field," they might, like the latter, have been lost. All show design, all take the leaf-form, and all aim at a point and a cutting edge. That partly thinned blades occur among them proves here, as at the other quarries, that these jasper "turtlebacks" are inchoate Indian spears, knives, or scrapers, unfinished, rejected, or lost; but which were "rejects," and which were lost, which were too cross-grained to be thinned down, and which were not, we leave to the Indian now living, who forty years ago was making stone arrow-heads on the Sacramento, to tell us. The point is almost immaterial; the main fact remains that all obviously are steps in the process of fashioning.

(d.) The thinned-down blade, still very rude but of recognizable Indian pattern, of which we found 29 specimens, 7 were only fragments, 4 would have measured 5 inches in length and done for large spears, 14 would have worked into arrow-heads. There was nothing like a buried cache of blanks to prove exactly how far the chipping work was carried at any one time at the quarries or that it always stopped at the same degree of finish. Sometimes it may have been large or small thinned ill-worked blades that were bundled up and carried off; sometimes pressure-finished knives or spears; sometimes back-breaking loads of "turtlebacks" themselves, heavy but still workable; while that the Indian sometimes carried away still heavier raw lumps is proved by a mass of native brown jasper weighing eight pounds found on the village site of upper Blacks' Eddy, ten miles from the nearest (Durham) quarry, and a smaller fragment noticed at the Frys' Run site, about five miles from the Durham diggings. On the other hand, two perfect arrow-heads of jasper and a curious notched jasper form (which I suggest was used instead of the notched bone in the finer chipping) found close to the pits seem to prove that the process was sometimes completed there, while two broken quartzite arrow-heads, a third of argillite, and a fourth of quartz point to material found and work done elsewhere. But granting all this, the immensely greater proportion of rougher forms places it beyond a doubt that the rude preliminary work above described and little else characterized the immediate quarry sites.

That the traces of thinned blades were so much rarer than the "turtlebacks" in the refuse was doubtless because they had reached a stage when they were more valuable to the maker, and when they would have been discarded far less often than the rough half-tested forms. That they represented the later steps in the work of which the "turtlebacks" were the beginnings, there could be no doubt.

A few blows of the pebble-hammer gave us the rough, leaf-shaped profile; others more careful and probably dealt with the smaller hammers produced the unmistakable closer chippings all round; then, if the mass, ceasing to be tractable, were not thrown away, still finer work—possibly pressure, was applied until the "turtleback" was thinned down to the last-mentioned form—which already in some cases as well finished as the stone knives found in Arizona cliff dwellings, still lacked the final notching and finishing touches to specialize it into a completed spear.

The Quarries as Places of Habitation

Quarrymen dwelt at the diggings for prolonged intervals—must have done so. How can we doubt it when we consider the amount of work done, which, at Macungie, may be roughly estimated at one million cubic feet of earth excavated and carried from pit to pit. On the bottom of one of the shallow pits at Durham I found the jaw and teeth of a deer mingled with charcoal and ashes, and, as the quarrymen must have eaten while they worked, similar fire sites must exist at Macungie. The three fragments of polished celts above mentioned found with the refuse, the four arrow-heads of foreign material and a fragment of unio shell found in shaft 18, attest habitation, and no doubt systematic search will discover pottery and all the other traces of regular Indian occupation near the pits.

Yet, admitting all this, when we consider how scarce these relics are and realize the position of the quarries, sometimes on high slopes and frequently in exposed positions and removed from the spring, that desideratum of the Indian village, we see plainly that they were rather mining camps than village sites.

Resemblances of the Quarry Turtleback

But the study of these quarries brings us beyond the bounds of Indian archeology and the interest that clings to their flaked stones lies not in what these are, but what they can tell us about the flaked stones of other ages and peoples.

The chief thing to be noticed about them is, and recent discussion has impressed the fact, that they resemble the so-called implements of alleged older peoples in the Age of Stone.

They look like Trenton specimens, like certain European neolithic quarry specimens (Spiennes and Cissbury), like certain among the Somme, Thames, Marne and Onse valley specimens, and when we have realized this we see that the important thing about quarries all over the world is not the "turtlebacks," for they seem common to many and characteristic of none, but the resultant blade for which the "turtlebacks" were made.

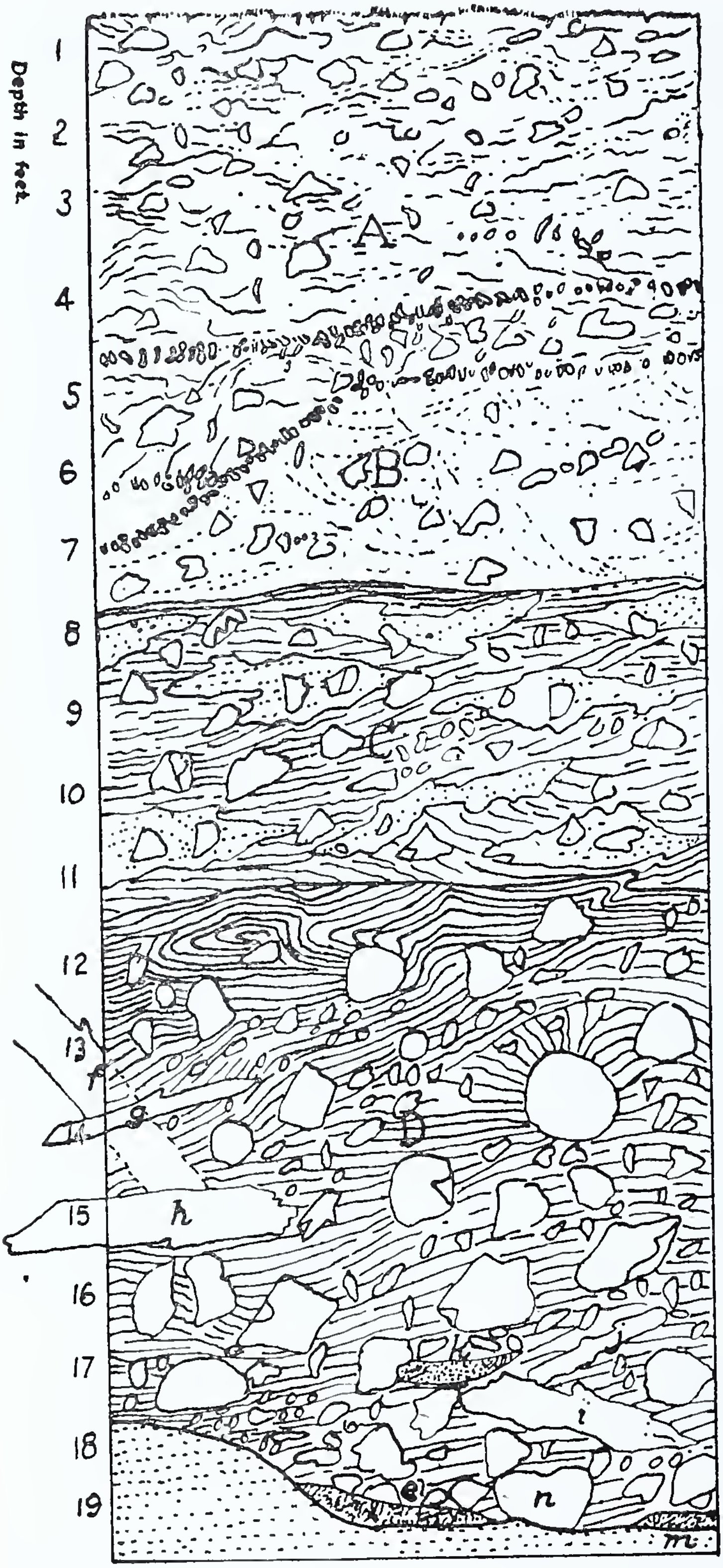
Fortunately we can find—if we look hard enough—arrow-heads (Flint Ridge, Saucon Creek, and Macungie); pitted hammerstones (Gaddis' Run), pointed wooden billets (Macungie), polished celts (Macungie and Grimes' Graves), pottery (Spiennes), and fossil bones (Abbeville), at such places to tell whether they are the workshops of North American Indians, of the Neolithic celt-makers of Belgium, or of the Drift Men of France and England, but outside of these culture and age tests we find a site marking difference of *result* aimed at in the different workshops named.

At Spiennes the "turtleback" turned to a celt; at Abbeville, if it turned to anything, to a *coup de poing;* at the North American quarries to a cache-blade spear or arrow-head, while if we could see the Mount Hope greenstone quarry or the Gippsland River-bed workshops in Australia (R. Brough Smith's "Aborigines of Victoria," p. 378), we should no doubt see it again fading into the so-called "tomahawk."

While, then, in three epoch-denoting classes of workshops—European drift, European neolithic, and North American Indian—we have the "turtleback," we must allow that the fact that a thing is a "turtleback" is neither for or against its antiquity. Bereft of its fellow-specimens from the quarry or workshop, wanting therefore a clue as to the intent of its maker, without geological horizon or associated relic, it must remain dateless and unlabeled.

Returning to the Lehigh Hills' quarries, a study of their topography makes us believe that the Indian dwelt some time in the valley of the Delaware before he discovered and worked them, and meanwhile as an inhabitant of the larger streams, chipped blade material in the form of beach-exposed pebbles. The recent discovery of argillite quarries at Gaddis Run, on the Delaware, in May 1893 (after the preceding pages were written, *i. e.*, in November, 1892), and the study of the neighboring river shores seemed to divide the large group of argillite "turtlebacks" there found into two classes—those of the quarry and those of the riverside, distinguishing between quarry chipping places, where "turtlebacks" were made at a late period of Indian occupancy systematically and by skilled workmen from material excavated inland, and riverside chipping places of an older time, where "turtlebacks" were made along the riverside from surface material there at hand.

And these riverside workshops it was which, when we came to push investigation abroad and into earlier geological horizons, seemed analogous to the specimen-bearing sites of the drift.



A—Clay and loam, jasper chips and charcoals with two layers of jasper chips at bottom.

B—Yellow ocherous clay, mixed with chips, charcoal, etc.

C—Brown earth or loam, interlaid with masses of yellow ocherous clay like B; the whole mixed with chips, nodules, and scattered bits of charcoal; 11th foot, blocked-out jasper blade; also small jasper blade.

D — Dark-brown earth or clay, mixed with smaller lumps of yellow clay, jasper nodules, charcoal, and containing: e, k, m, fireplaces; f, mould of tree; h, charred mould of tree; j, charred mould of branch; i, mould of tree sharpened at end; g, mould of sapling sharpened at end; and n, large stone implement; 16th foot, large quartzite "turtleback"; also blocked-out blade of jasper; also small blocked-out blade of jasper; 16th foot, small piece of unio shell.

Undisturbed pure yellow and white ocherous clay at bottom, 18½ ft. down, in which one small jasper nodule was found.

Figure 1. Section of shaft sunk in Indian jasper mine near Macungie. Shows arrangement of refuse layers, fire sites, pointed wooden billets, and jasper blades.

Early White Settlers

The date of the earliest settlement of Lehigh County is decidedly indefinite. We are told that white traders came into the Lehigh Valley as early as 1701 to barter with the Indians, but it was considerably later that any permanent settlers arrived. German immigrants are believed to have located in Lower Milford Township about 1715. Some records indicate that as early as 1719 Peter Trexler settled along Spring Creek, where Trexlertown is now. Certainly many families settled in the region before 1730. Practically all the early arrivals were Germans who had landed in Philadelphia and, seeking homes, pushed northward beyond the already occupied portions of Pennsylvania. Some were persons who had bound themselves to work out their passage costs after landing and were known as Redemptioners. The shipping companies sold the services of these people to farmers mainly for periods up to three years. At the expiration of their terms they were free to locate farms for themselves. These redemptioners came mainly between 1728 and 1751.

Most of the immigrants came from the Palatinate. A variety of reasons caused them to emigrate, but principally religious persecution and economic distress. They came to Pennsylvania rather than elsewhere because agents of William Penn circulating through their homelands of the Rhine region had spread the reports of ''peace, liberty and fertile soil'' that they could secure and enjoy in Penn's colony.

The first settlers entered the region from the south, now Bucks, Montgomery, and Berks counties, and occupied Lower and Upper Milford and Upper Saucon townships. But soon they crossed South Mountain and located in the wide limestone valley, which was more to their liking. One historian has expressed the idea that the German farmer was especially desirous of obtaining limestone land. However, he found few streams in the limestone sections, so many a compromise had to be made. Later arrivals pushed northward into the slate regions, doubtless attracted by the numerous springs in the valleys.

There seem to have been few organized groups of colonists among the first settlers in Lehigh County. In the main they came as single families and settled themselves where they could. With few exceptions they were poor and of limited educational and cultural background, characteristics common to first settlers in every new country. In general they possessed unusual initiative and courage and were deeply religious, industrious, and of hardy stock. Many of the present residents have reason to be proud of such an ancestry. They suffered unanticipated privations, but with fortitude of spirit overcame obstacles and discouragement as they came along, and laid the foundation for the prosperity and happiness enjoyed by their descendants.

The settlers in the northwest section of the county and adjoining portions of Berks County had crop failures at times so that that region received the name of Alle-Mängel (lacking everything). They traveled eastward for food and other supplies and the region of succor was named Egypt, a name which still survives but with Alle-Mängel not entirely obsolete.

The only organized group of the region was the band of Moravians that founded Bethlehem in 1741. They came with a fixed purpose to serve as missionaries to the Indians. Their history more properly belongs to Northampton County, although very early they extended their activities beyond its borders. The Indian village of Nain, built by them, was in Lehigh County, and a Moravian group settled early at Emmaus and gave it its biblical name.

Improvements of different kinds came rapidly, but the first community need was for better transportation facilities. In 1735 the first road was laid out. By present locations it extended from about one-fourth mile northwest of Breinigsville, through Macungie, Shimersville, Old and New Zionsville, Hosensack, and thence to North Wales in Montgomery County, where it connected with an existing road to Philadelphia. Other roads quickly followed.

The government of the region was a matter of early concern. When the first settlers arrived the section was part of the original Bucks County, one of the three original counties established by William Penn in 1682. The distance to the county seat and the travel difficulties necessitated smaller units as the settlements increased. On March 11, 1752, Northampton County was established and on March 6, 1812, a portion was separated to constitute Lehigh County. Division into townships also progressed during a period of years. The first township to be organized was Upper Milford in 1737. It later was divided into Upper and Lower Milford. Saucon Township was established in 1743, but at the time included both Lower Saucon Township, Northampton County, and Upper Saucon Township, Lehigh County. The early erection of these two townships indicates the rapidity with which the region was settled. The establishment of other townships by division and alteration continued over a long period.

For many years after its settlement, German was the almost universal language in Lehigh County. The German used was in the beginning the dialect of the Palatinate, but in time many corruptions crept in until Pennsylvania German (erroneously frequently called ''Pennsylvania Dutch'') gradually became essentially a distinct dialect and was carried far beyond the borders of Pennsylvania. Although still in common use, especially among the older residents, generally the children of today are unable to speak it. The rapid decrease in use of the dialect during the past few decades has been brought about by its ban in the public schools, good roads and automobiles, rural free mail delivery, the telephone, and the radio.

The further history of Lehigh County is not pertinent to this report. Mills were erected along the streams, taverns opened along the roads, and gradually shops, factories, and villages came into existence. Starting as a purely agricultural region it has gradually passed into a highly industrial one. The population also has become far more mixed as immigrants later came from more varied sources. The development of the various industries of the region will be discussed in later chapters.

Bibliography

Even though some repetition is involved, in that titles given below are also included in the general bibliography, a short selected list of the most important historical publications dealing with Lehigh County is given here. The earliest works deal mainly with the Indians. The Moravian Archives, Bethlehem, contain a wealth of material concerning the early settlement of the Lehigh Valley.

Loskiel, Georg Heinrich. Geschichte der Mission der evangelischen Brüder unter den Indianen in Nordamerika.
784 pp., Barby, Leipzig, 1789.
See Loskiel 1794.

Loskiel, George Henry. History of the Mission of the United Brethren among the Indians in North America.
Translated from the German by Christian Ignatius LaTrobe.
In three parts, pp. 159, 234, 233. Index (19 pp.), London, 1794. (Copy in Lehigh University Library contains map 16″x18½″ of "Part of the United States of America, published 15th Nov. 1798 by J. Stockdale, Piccadilly." The map shows "those places in which the Christian Indians resided.")
An extremely interesting narrative which portrays life and character of the Indians who inhabited this region.

Heckewelder, Rev. John. An Account of the History, Manners, and Customs of The Indian Nations, who once inhabited Pennsylvania and the Neighboring States.
348 pp., published by the Amer. Philos. Soc., Phila., 1818. A German translation by Fr. Hesse was published in Göttingen in 1820 and a French translation by Du Ponceau in Paris in 1822. Republished in a "New and Revised Edition with an Introduction and Notes by Rev. William C. Reichel" as Vol. XII of the Memoirs of the Historical Society of Pennsylvania, Philadelphia, 1876.

Heckewelder, John. A Narrative of the Mission of the United Brethren among the Delaware and Mohegan Indians, from its commencement, in the year 1740, to the close of the year 1808, comprising all the remarkable incidents which took place at their missionary stations during that period, interspersed with anecdotes, historical facts, speeches of Indians, and other interesting matter.
429 pp., Philadelphia, 1820.

Rupp, I. Daniel. History of Northampton, Lehigh, Monroe, Carbon and Schuylkill Counties: containing a Brief History of the First Settlers, Topography of Townships, notices of leading events, incidents, and interesting facts in the early history of these counties: with An Appendix, containing matters of deep interest. Embellished by several engravings.
554 pp., Harrisburg, 1845.

Henry, M. S. History of the Lehigh Valley, containing a copious selection of the most interesting facts, traditions, biographical sketches, etc., relating to its History and Antiquities, with a complete history of all its internal improvements, progress of the coal and iron trade, manufactures, etc. . . . Illustrated by numerous engravings.
436 pp., Easton, 1860.

de Schweinitz, Edmund. The Life and Times of David Zeisberger, Western Pioneer and Apostle of the Indians.
747 pp., Philadelphia, 1871.

Davis, F. A. New Illustrated Atlas of Lehigh County, Pennsylvania.
72 + 37 pp., 50 maps, Reading Publishing Co., Reading, Pa., 1876.

MATHEWS, ALFRED, and HUNGERFORD, AUSTIN N. History of the Counties of Lehigh and Carbon, in the Commonwealth of Pennsylvania.
802 pp., illustrated, Philadelphia, 1884.

RICHARDS, HENRY M. M. The Indian Forts of the Blue Mountains, Vol. 1, pp. 3-347 of Report of the Commission to Locate the Site of the Frontier Forts of Pennsylvania.
2 vols., 627 pp. and 636 pp., Harrisburg, 1896.
Second edition edited by Thomas Lynch Montgomery published in 1916, Harrisburg.

MERCER, HENRY C. The Antiquity of Man in the Delaware Valley.
Reprinted from publications of the University of Pennsylvania, Vol. VI.
85 pp., 30 figs., Boston, 1897.

LEVERING, JOSEPH MORTIMER. A History of Bethlehem, Pennsylvania, 1741-1892 with some account of its founders and their early activity in America.
809 pp., maps and figs. Bethlehem, 1903.

HURLBUT, ARCHER BUTLER and SCHWARZE, WILLIAM NATHANIEL, Editors. David Zeisberger's History of the Northern American Indians.
Ohio State Archæological and Historical Society, 189 pp., 1910.

ROBERTS, CHARLES RHOADS, STOUDT, JOHN BAER, KRICK, THOMAS H. and DIETRICH, WILLIAM J. History of Lehigh County, Pennsylvania, and a genealogical and biographical record of its families.
Two vols., 1101 and 1467 pp., Allentown, 1914.

DEVELOPMENT OF KNOWLEDGE OF THE GEOGRAPHY AND GEOLOGY OF LEHIGH COUNTY WITH BIBLIOGRAPHY AND CARTOGRAPHY

By Benjamin L. Miller

The region embraced within the present limits of Lehigh County was first visited by white men about 1701. So far as known these earliest visitors left no written record of their observations, a situation that prevails likewise with the still earlier inhabitants, the Delaware Indians.

The earliest contributions to our knowledge of the area were made by explorers and travelers, some of whom have left records of careful and exact observations. An example of exaggeration or fantastic description is the work of Gottlieb Mittelberger, who made a journey to Pennsylvania in the years 1750-1754, and returning to Germany related many a ''tall story'' of his experiences and the objects he had seen.

The map-makers, geographers, geologists, and historians also began their work soon after the first settlements were made and have continued to add to our knowledge down to the present at an almost steadily increasing rate. For the past 100 years there is scarcely a year without some worthwhile contribution.

Naturally the titles contained in the bibliography and cartography are of unequal value. In many the information is indefinite, fragmentary and, in certain cases, incorrect. Certain articles are, in large part, merely repetitions of previous ones. All that have come to the attention of the writer have been listed, regardless of their merits or demerits, with the idea in mind that time and effort may be saved thereby for future investigators.

In this 200-year record the writings of a few men stand out so prominently as to deserve specific mention. For the first century these are James Scull, Nicholas Scull, W. Scull, Lewis Evans, William Maclure, frequently called the ''Father of North American Geology,'' and Parker Cleaveland.

The second century opened the era of systematic investigations by trained scientists. In 1836 the First Geological Survey of Pennsylvania was established with the brilliant geologist, Henry D. Rogers, as Director. In his Second Annual Report published in 1838 he laid the foundation for all later geological and geographical work in the region. In his succeeding Third, Fourth and Fifth annual reports and in the comprehensive Final Report (1858) he supplied a mass of data that still possesses much value and must be consulted by all present-day workers. More detailed studies have been made since that time and many explanations have been modified, yet little change has been made in the basal concepts of Rogers and his co-workers as expressed in their writings between 1836 and 1858.

Between the close of the First Geological Survey and the beginning of the Second Geological Survey of Pennsylvania in 1874, the contributions were less numerous and in general of minor importance. Articles descriptive of the Friedensville zinc mines appeared during this time and some historical publications containing important geographical material.

The Second Geological Survey, 1874 to 1895, was under the direction of J. Peter Lesley, who seems to have visited Lehigh County on numerous occasions. Several other members of the Survey were also interested in specific problems, but the major investigations were made by Frederick Prime, Jr., who was especially assigned to the Lehigh Valley. Prime devoted most of his attention to the iron mines, which at that time were being worked most actively. However, he did considerable stratigraphic and structural work in addition to his economic studies. R. N. Sanders studied the slate quarries and F. A. Genth collected information concerning the minerals for the Survey. Also Dr. Edgar F. Smith, then Professor of Chemistry in Muhlenberg College, likewise contributed to our knowledge of Lehigh County minerals.

From the close of the Second Survey until the establishment of the existing Fourth Survey little systematic geological work was carried on in the region. Occasional articles, mainly pertaining to the economic mineral resources, were published. Most of these were prepared by the staff members of the geological departments of Lafayette College and Lehigh University. Three of the investigators of this period are worthy of special mention. They are the late Dr. Edward H. Williams, Jr., the late Dr. Frederick B. Peck, the head of the Department of Geology in Lafayette College for many years, and Dr. Edgar T. Wherry, now a member of the botanical department of the University of Pennsylvania. The contributions of these men are of great importance.

Bibliography and Cartography

1715

MOLL, HERMAN. A New and Exact Map of the Dominions of the King of Great Britain on ye Continent of North America.

London, 1715 (Dedication gives date of 1711). 26″x40″. Scale 1 inch = 60 miles. Moravian Archives.

It appears that no information in regard to the regions embraced in Lehigh County was available. The "Perquemuck" (Schuylkill) River flows almost parallel to the "Dellaware" River to its junction at Philadelphia.

1738

SCULL, JAMES. Manor of Macungy. Tract of Land Situate in Macungy & Whitehall Townships in County of North Hampton containing two thousand one hundred & forty seven acres and 101 perches with allowance of 6 per cent by James Scull.

13¾″x17¾″. Pennsylvania Archives, 3d ser., vol. 4.

A very irregular tract. Owners of adjoining properties are named.

1740

EASTBURN, BENJAMIN, Surveyor General. A Draught of Sundry Tracts of Lands, surveyed to Divers purchasers in ye Forks of Delaware River, and on, and near the West Branch of said River, in ye County of Bucks.

Drawn in the year 1740, by Benja. Eastburn, Surv'r. Gen'l. 21″x33″. Scale: 1 inch = ⅞ mile. Hist. Soc. of Pa., Moravian Archives.

Manuscript map. Shows ownership of various tracts, many belonging to William Allen. The Lehigh River is called the West Branch of the Delaware. "Menakasie" creek, "Leheigh" (Little Lehigh) creek. Map covers area embracing location of present towns of Easton, Bethlehem, Allentown, Coplay, etc.

1749

Evans, Lewis. A map of Pensilvania, New-Jersey, New-York and the Three Delaware Counties by Lewis Evans, MDCCXLIX.

19″x26″. Scale: 1 inch = 15 miles. Pennsylvania Archives, Third Series, Appendix Vol.

See Gipson, L. H. 1939.

"Groushall" (generally written Grousehall) (Hunting lodge of Lynford Lardner) is only place named in Lehigh County. Bethlehem is written "Bethlem." South Mountain is called "Leheigh Hills" and the range on the north side of the county is called "The blue mountains or the Kittatinny M." Cedar, Truckers (now Jordan), and Trout creeks are shown.

Different descriptions are printed on margins of map, including a fairly accurate one of the weather.

This map with some revision was republished in 1752.

1750

Evans, Luderico (Lewis). Pensilvaniæ, Nova-Caesareæ, Nova-Eboraci, Aquanishnonigæ et Canadæ, brevis delineatio juxta Hinera P. Kalm a Luderico Evans 1750.

This is Evans' map drawn for Peter Kalm. The Lehigh County region is a smaller scale representation of the 1749 map.

1752

Anonymous. Northampton County. Map 17½″x19″. Scale: 1 inch = 5¾ miles.

Original in Amer. Phil. Soc., Phila. Photostat in Hist. Soc. of Pa. Is dated 1752 but contains much later data such as names of counties (Lehigh, Carbon, Monroe, Pike, etc.) erected long after that date. It is possible that this map was later changed.

A generalized manuscript map which includes the entire territory lying north of Bucks County to the New York State line and westward to the Schuylkill River.

1753

Anonymous (Probably C. G. Reuter). Bethlehem Tract with all the Adjacent Lands, 1753 (?).

18½″x30″. Scale 1 inch = about 3.75 perches. Hist. Soc. of Pa. Pen and ink, partly colored. Scale incorrect; area larger.)

Sawmills on Sand Island along Monocacy Creek. Opposite it along Lehigh River "S. (single) Sr's. washhouse." "S. (single) Breth. washhouse" along Lehigh River to the west about where silk mill now stands.

Evans, Lewis. A Brief Account of Pennsylvania, 1753.

Two manuscripts exist in the libraries of the Historical Society of Pennsylvania and The Library Company of Philadelphia, neither of which is the original. Published recently by L. H. Gipson. See Gipson, L. H. 1939 in this bibliography.

Contains an interesting description of the Great Valley in which the greater portion of Lehigh County is situated.

"Between the Kittatinni Mountains, & a smaller Chain of Hills, which we call by several names, as Lexey (Evans' name for Lehigh) Hills, Oley Hills, Flying Hills, & South Mountain etc., there is a fine Valley from 8 to 12 Miles wide, which extends under different Names, from New Jersey to Georgia, above 800 miles, the Stone of it is mostly Limestone, and the Soil, very good. A very singular appearance runs thro' all the little Hills, above mentioned, they seem'd formerly not to have belong'd to the Soil, but to have been laid a top of the Ground: The same Stratum extends under them, from one Side to the other, & where they are broken for the passage of Rivers the Lime Stone & other Strata, are everywhere obvious under them, & The same Phoenomena, attend most other little Hills."

1755

Evans, Lewis. A General Map of the Middle British Colonies in America by Lewis Evans. 1755.

Map 20″x26″. Scale: 1 inch = 35± miles. Pennsylvania Archives, 3d ser., app. vol. Moravian Archives.

Differs only slightly from Evans' 1749 and 1752 maps. Trout, Truckers (Jordan), Lexey (Little Lehigh), and Saucon (probably Ontelaunee) creeks are shown.

Evans, Lewis. Analysis of a Map of the Middle British Colonies in America.

32 pp., Philadelphia, 1755.

Describes in a general way the topography and drainage of the region. "The South Mountain is not in Ridges like the Endless Mountains, but in small, broken, steep stony Hills; nor does it run with so much Regularity. In some Places it gradually degenerates to Nothing, not to appear again for some Miles, and in others spreads several Miles in Breadth. Between the South Mountain and the higher Chain of the Endless Mountains, (often for Distinction called the North Mountain and in some Places the Kittatinni, and Pequilin), there is a Valley of pretty even, good Land, some 8, 10 or 20 Miles wide, which is the most considerable Quantity of valuable Land that the English are possest of; and runs through New-Jersey, Pensilvania, Mariland and Virginia. It has yet obtained no general Name, but may properly enough be called Piedmont, from its Situation. Besides Conveniences always attending good Land, this Valley is everywhere enriched with Limestone." (p. 7.)

"The West Branch of Delaware" (the Lehigh River) "is but inconsiderable, compared with the North-Eastern Branch, into which it fails at Easton." (p. 21.)

1756

Mittleberger, Gottlieb. Reise nach Pennsylvanien im Jahr 1750 und Rükreise Deutschland im Jahr 1754.

Stuttgart, 1756.

See Eben, Carl Theo., 1898 for translation.

1758

Anonymous. Map extending from Forks of the Delaware (Easton) to Maccongy (Macungie) north of "Lehi" Hills. "Copy 1758."

11″x15″. Scale: 1 inch = 400 perches. Hist. Soc. of Pa.

Not much information.

Reuter, P. C. G. Historical Map of the Moravian Lands at Bethlehem. Based upon a map drawn by P. C. G. Reuter, March, 1758.

14″x17″. Scale: 1 inch = 100 rods. Pen and ink drawing. Hist. Soc. of Pa.

Shows location of Nain, about 250 rods west of Monocacy Creek and north of small tributary. South Mountain is named "The Lecha Mountain."

1759

Anonymous. Draft of the Lands in Salisbury which Jacob Ehrenhardt and Sebastian Knauss donated to the Moravian Settlement (Gemein Ort.) in that Township. Surveyed April 10, 1759.

16½″x27″. Scale: 1 inch = 10 rods. Pen and ink drawing, partly colored. Hist. Soc. of Pa.

Shows ownership of several tracts along the Little Lehigh Creek.

Scull, Nicholas. Map of the improved Part of the Province of Pennsylvania by Nicholas Scull. 1759.

30″x60″. Scale: 1 inch = 3.8 miles. Pennsylvania Archives, 3d ser., app. vol.

Several townships are named. The Lehigh River (called West Branch of the Delaware), Trout, Jordan and Leheigh (Little Lehigh) creeks are shown. Settlements or single homes are located such as Truckers mill (near mouth of Trout Creek, Grousehall (west of present Allentown), Trexler (Trexlertown), Kims (northwest of Trexler), Billman Mill (near present Delhertsville), Hinkle (near site of Shimerville), Crall (near site of Zionsville), and Plumsted on Cedar Creek.

1760

ANONYMOUS. A Draught of Several Roads going through Bethlehem Land. 1760.

15½″x16″. Scale: 1 inch = 200 perches. Pen and ink drawing. Hist. Soc. of Pa.

Shows location of "Nain, ye Indian Town" on west side of "Manokasy" Creek and north of stream coming in from west, south of present location of paint mill. This stream shown heading in spring. Sawmill on Sand Island. "Allen's Town" is shown. Roads to Philadelphia, Easton, Nazareth, Fort Allen, Allentown and Reading are called King's Roads.

GARRISON, NICHOLAS and KOLOKOFSKY (GOLGOWFSKY), GEORGE WENCESLAUS. A Draft of Four Fording Places over the Lehigh near Bethlehem. Surveyed Oct. 2, 1760, by Nicholas Garrison, Jr., and Geo. Wenceslaus Kolokofsky (Golgowfsky).

12″x33″. Four ink sketches. Scale: 1 inch = about 8.8 rods. Hist. Soc. of Pa.

The highest ford is about one mile above Bethlehem near the Geissinger Farm, the lowest two miles below Bethlehem.

1762

ANONYMOUS. Northampton Town. Surveyed by Order of William Allen, Esq., 1762.

16½″x17″. Scale not given. Hist. Soc. of Pa.

This map indicates that Allen himself chose the name Northampton Town for what is now Allentown.

1770

SCULL, W. A map of Pennsylvania exhibiting not only The Improved Parts of that Province but also Its Extensive Frontiers laid down From Actual Surveys and Chiefly from the late map of W. Scull, published in 1770.

24″x48″. Scale: 1 inch = 6 2/3 miles. Pennsylvania Archives, 3d ser., app. vol.

Several streams appear on map, such as West Branch of Delaware (Lehigh), Leheigh (Little Lehigh), Jordan or Truckers, and Trout creeks. The estates of Grousehall and Plumsted are shown. Northampton is name given to present city of Allentown.

SCULL, W. The Province of Pennsylvania, by W. Scull, Philadelphia, 1770.

21″x31″. Scale: 1 inch = 9 miles. Pennsylvania Archives, 3d ser., app. vol.

Only a few streams, mountains, and towns in Lehigh County named. Allentown appears as "Northampton." South Mountain called "Lehi Hills."

1777

SAUTHIER, C. J. A map of the Provinces of New York and New Jersey with a part of Pennsylvania and the Province of Quebec from the Topographical Observations of C. J. Sauthier. Augsburg, 1777.

29″x40″. Scale: 1 inch = 12½ miles. Pennsylvania Archives, 3d ser., app. vol.

Very few names and topographic features in Lehigh County. South Mountain is called "Leheihg Hills," possibly a typographic error and intended for Leheigh. Nothing shown in Lehigh County except West Branch of the Delaware (Lehigh) River and Leheihg Hills (South Mountain).

1788

SCHÖPF, JOHN. Reise durch einige der mittlern und südlichen vereinigten nordamerikanischen Staaten. Unternommen in den Jahren 1783 und 1784.

Two parts, Erlangen 1788. Translated with title, Travels in the Confederation (1783-1784), and edited by Alfred J. Morrison, 2 vols., 426 pp., 344 pp., Philadelphia, 1911.

See Schoepf, 1911.

1792

Howell, Reading. A Map of the State of Pennsylvania by Reading Howell, 1792.

36″x62″. Scale: 1 inch = 5 miles. Pennsylvania Archives, 3d ser., app. vol. Moravian Archives.

Shows course of Lehigh River, Jordan, Trout, Little Lehigh, Hosasock (Hosensack), and Maiden creeks. Several mills and residences are located, some of which are named.

1794

Cazenove, Theophile. Journal, Manuscript in French.

75 pp., 1794. Translated from the French by Rayner Wickersham Kelsey, 103 pp. and map. Haverford, 1922.

See Kelsey, 1922.

Loskiel, George Henry. History of the Mission of the United Brethren Among the Indians in North America.

Translated from the German by Christian Ignatius LaTrobe. Three parts, 159, 234, 233 pp. Index and map. London, 1794.

Contains some items of geographic interest. An excellent account of the Indians that formerly occupied this region.

1795 circa

Allum, John and Wallis, John. Map exhibiting a General View of the Roads and Inland Navigation of Pennsylvania and part of the adjacent States, by John Allum and John Wallis.

29½″x33″. Scale: 1 inch = 9 miles. Pennsylvania Archives, 3d ser., vol. 1.

Very few places named in what is now Lehigh County. What is now Allentown appears as "Northampton." A ferry just below mouth of Hokendauqua Creek is named "Fousts Ferry." Lehigh River appears as "Lehi River."

1800

Anonymous. Plan of the Road, laid out by order of Court from the Easton Road, thro' Bethlehem to the Berks County Line in Upper Milford Township (no date, perhaps about 1800).

7½″x54″. Scale: 1 inch = 100 perches. Pen and ink drawing. Hist. Soc. of Pa.

Ownership of various tracts shown. Shows 3 mills along the Little Lehigh and one on tributary coming in from the south.

1805

Ogden, John C. An Excursion into Bethlehem & Nazareth in Pennsylvania, in the year 1799.

167 pp., Philadelphia, 1805. Earlier edition published in 1800.

Describes the large spring at Allentown. Some of the clay industries (stove tile and clay pipes) of Bethlehem described were located in what is now Lebigh County.

1807

Mease, James. A Geological Account of the United States.

510 pp., Philadelphia, 1807.

Gives several brief descriptions of the topography and geology of the Lehigh Valley. Says "the limestone generally lies in a state of confusion, and as it were jumbled together by violence." (p. 46.)

1809

Maclure, William. Observations on the geology of the United States, explanatory of a geological map.

Am. Philos. Soc. Trans., vol. 6, pp. 411-428, map, Philadelphia, 1809. Journal de physique, de chimie, d'histoire naturelle et des arts, vol. 69, pp. 204-213, Paris, 1809.

Has brief references to the distribution of the "Primitive" (pre-Cambrian) crystalline rocks and the "transition" (Lower Paleozoic) sedimentary rocks of eastern Pennsylvania with mention of localities near Bethlehem and Easton. The accompanying generalized geological map is the first to show the regions of Lehigh and Northampton Counties.

1811

HOWELL, READING. A Map of the State of Pennsylvania.

22″x33″, 1811.

Townships of Northampton County (which at that time included what is now Lehigh and portions of Carbon and Monroe Counties) are named. A few towns are also named.

1816

CLEAVELAND, PARKER. An Elementary Treatise on Mineralogy and Geology.

668 pp., Boston, 1816. 818 pp., Boston, 1822. Revised edition in two volumes.

Brief descriptions of some minerals from Lehigh and Northampton counties. More described in later edition.

1817

MACLURE, WILLIAM. Observations on the geology of the United States of America. 127 pp., map, Philadelphia, 1817.

Review by C. S. Rafinesque, Am. Mo. Mag., vol. 3, pp. 41-44, New York, 1818.

Has brief references to distribution of the "primitive" (pre-Cambrian) crystalline rocks and the "transition" (Lower Paleozoic) sedimentary rocks of eastern Pennsylvania, with mention of localities near Bethlehem and Easton.

1818

MACLURE, WILLIAM. Observations on the geology of the United States of America.

Am. Philos. Soc. Trans., new ser., vol. 1, pp. 1-91, map, Philadelphia, 1818.

Has brief references to distribution of the "primitive" (pre-Cambrian) crystalline rocks and the "transition" (Lower Paleozoic) sedimentary rocks of eastern Pennsylvania, with mention of localities near Bethlehem and Easton.

MITCHILL, SAMUEL L. Observations on the Geology of North America.

Appendix to Georges Cuvier's "Essay on the Theory of the Earth," pp. 321-431, New York, 1818.

Advances the idea that there were "barriers which probably restrained the waters, in some parts of North America, after the Ancient Ocean had retired." Believes that Blue Mountain was such a barrier or dam "by which the waters were restrained for a considerable time." In describing the Delaware Water Gap he says "the vastness of the dismemberment impresses every traveller with a sense of its present grandeur, and of the prodigious force necessary to rend the mountain from its summit to the base." Lehigh Gap was formed in a similar way. Before the bursting of the mountain at Lehigh Gap and Delaware Water Gap, the water of the sea was partially discharged through the Wind Gap.

1822

CLEAVELAND, PARKER. An Elementary Treatise on Mineralogy and Geology, 818 pp., second edition, Boston, 1822.

"In Pennsylvania, at Allentown, a Buhrstone or cellular quartz is found and employed for millstones (Cooper)" (pp. 265-266). Also says basanite occurs "in Pennsylvania near Reading and Bethlehem" (p. 300). Includes a small scale geologic map of the eastern part of the United States.

HECKEWELDER, JOHN. Names which the Lenni Lenape (Lennape) or Delaware Indians gave to Rivers, Streams and Localities within the States of Pennsylvania, New Jersey, Maryland and Virginia with their Significations.

See Heckewelder, 1872.

1825

Melish, John. Map of Pennsylvania constructed from the County Surveys authorized by the State and other original documents, 1825. Revised edition in 1832.

52″x75″. Scale: 1 inch = 5 miles.

Names townships, towns, streams. Contains insets giving "statistical & Geological Remarks." Gives "South Mountains or Lehigh Hills." Sinking River located northeast of "Fogelsville." Gap east of Bake Oven Knob is called Kunkles Gap. "Northampton or Allentown."

Robinson, Samuel. A Catalogue of American Minerals with their localities, etc.

316 pp., Boston, 1825.

Lists several minerals from Lehigh County, including buhrstone or cellular quartz found near Allentown and employed for mill purposes, and basanite near Bethlehem. Most of the information was taken from Cleaveland's "Mineralogy."

1830

Tanner, H. S. Map of Northampton and Lehigh Counties, Pennsylvania, 1830.

18½″x21″. Scale: 1 inch = 2½ miles. Hist. Soc. of Pa.

Includes what is now Carbon and Monroe Counties as well as the present Northampton and Lehigh Counties. A generalized map. Has some unusual spellings and several place names not in use now.

1831

Silliman, Benjamin. Notes on a journey from New Haven, Conn., to Mauch Chunk and other Anthracite regions of Pennsylvania.

Am. Jour. Sci. and Arts, vol. 19, pp. 1-21, New Haven, 1831. Abstract, Register of Pennsylvania by Samuel Hazard, vol. 6, pp. 273-278, 1830.

Gives a description of the Lehigh River and particularly of the Lehigh Gap. Does not believe that the gap was mainly cut by the Lehigh River.

1832

Gordon, Thomas F. A Gazetteer of the State of Pennsylvania.

Part First 63 pp., Part Second 508 pp., map, Philadelphia, 1832.

Contains a brief description of the Lehigh Valley, principally abstracted from William Maclure's report (1818). A short description of each of the named geographic features of Lehigh County.

1833

Finch, I. Travels in the United States of America and Canada, etc.

455 pp., London, 1833.

Describes the Lehigh Water Gap and the flat top of Blue Mountain. He refers the conglomerates of the mountain to the "old red sandstone" (p. 110).

1835

Eaton, Rebecca. A Geography of Pennsylvania for the Use of Schools, and Private Families.

Contains brief descriptions of some of the geographic features of Lehigh County.

1838

Rogers, Henry D. Second Annual Report on the Geological Exploration of the State of Pennsylvania.

93 pp., columnar section and table (Two editions with slight differences). Harrisburg, 1838.

Describes sandstones (Hardyston) of South Mountain (pp. 20-23), limestones and iron ores of the Kittatinny Valley (pp. 23-30), slates (pp. 30-36), sandstones and conglomerates of Blue Mountain (pp. 36-39). Descriptions of specific iron mines, slate and limestone quarries, paint and clay deposits. Explains Delaware Water Gap and other water gaps as due to "transverse dislocations" (p. 79).

1839

ROGERS, HENRY D. Third Annual Report on the Geological Survey of the State of Pennsylvania.

119 pp., Harrisburg, 1839.

Brief descriptions of the Paleozoic sandstones and limestones of South Mountain and the small valleys lying southeast of Kittatinny Valley, such as Saucon Valley.

1840

ROGERS, HENRY D. Fourth Annual Report on the Geological Survey of the State of Pennsylvania.

215 pp., Harrisburg, 1840.

Gives five analyses of iron ore from mines northwest of Allentown, near Emaus and west of Trexlertown (pp. 178-180).

1841

ROGERS, HENRY D. Fifth Annual Report on the Geological Survey of Pennsylvania.

179 pp., Harrisburg, 1841.

Contains descriptions of the gneisses, Paleozoic sandstones and limestones of the southern portion of Lehigh County (pp. 16-30). Describes some magnetite and limonite iron mines (pp. 39-43), and a few occurrences of the Triassic conglomerates (pp. 43-45). Contains ten analyses of magnetite and brown iron ores (pp. 107-112) and three analyses of limestones (p. 161).

1843

MAXIMILIAN, PRINCE OF WIED. Travels in the Interior of North America (1832-1834). Translated from German by H. Evans Lloyd.

520 pp., London, 1843.

Occasional brief notes on the topography of the region and the rocks observed in his travels.

TREGO, CHARLES B. A Geography of Pennsylvania containing an account of the history, geographical features, soil, climate, geology, botany, zoology, population, education, government, finances, productions, trade, railroads, canals, etc. of the State; with a separate description of each county and questions for the convenience of teachers.

384 pp., Phila., 1843.

1845

RUPP, I. DANIEL. History of Northampton, Lehigh, Monroe, Carbon and Schuylkill Counties.

554 pp., illustrations. Harrisburg, 1845.

Contains many descriptions of the topographic and geologic features of Lehigh County, among which the following topics are of special interest: The Lehigh River (pp. 111-113) and the great floods of November 1840 and January 1841 (pp. 53-59, 84, 143). The Lehigh Water Gap (Die Lecha Wasser-Kaft) (pp. 113-115); and suggests a strange explanation for its origin. Describes springs and caves (pp. 130-131, 134, 143). Describes Breinigsville iron ore mine, which contains so much iron sulphide as to be shipped to Philadelphia for manufacture of copperas (p. 136). Big or Mammoth Rock (Bower's Rock) (pp. 139-140).

1850

HENRY, M. S. Map of Northampton County, Pennsylvania.

28″x35″. Scale: 1 inch = ¾ mile. In color. Printed by H. Camp, 1850. Hist. Soc. of Pa.

This map is of interest because it shows "Zinc Works" along the Lehigh River in "South Bethlehem" and indicates that Friedensville zinc ore at that date was being hauled into Bethlehem.

1851

LEA, ISAAC. On the bones of a reptilian quadruped from Lehigh County, Pa.

Acad. Nat. Sci. of Phila., Proc. vol. 5, pp. 171-172, 205, Phila., 1851.

Describes bones and teeth of a reptilian quadruped found in a calcareous conglomerate on Hassac's Creek (Hosensack) Creek, Upper (Lower?) Milford Township, Lehigh County, by Dr. Shelly.

1853

ANDREWS, T. Report on the Mines, Manufactures and Conditions of the Pennsylvania and Lehigh Zinc Company.

12 pp., New York, 1853.

ANONYMOUS. Pennsylvania and Lehigh Zinc Company.

Mining Magazine, vol. 1, pp. 544-546, New York, 1853.

An account of the zinc industry at Bethlehem and the new patent process of Mr. Wetherill for making zinc oxide from the crude ore. Notes the progress of the mining operations, still in the very early stages.

BLAKE, W. P. On the occurrence of Crystallized Carbonate of Lanthanum.

Am. Jour. Sci. and Arts (2d ser.), vol. 16, pp. 228-230, New Haven, 1853.

Describes a specimen of lanthanite found at the Friedensville zinc mines. Gives crystal measurements and chemical analyses.

LEA, ISAAC. Description of a fossil saurian of the New Red Sandstone formation of Pennsylvania; with some account of that formation.

Acad. Nat. Sci. of Phila., Jour., sec. ser., vol. 2, pp. 185-202, 3 plates, Phila., 1853.

Refers to the bones of a "reptilian quadruped" found in a calcareous conglomerate on Hassac's (Hosensack) Creek, Upper (Lower?) Milford Township, Lehigh County and described in the Proceedings of the Acad. in 1851, pp. 171-172, and 205.

1854

ANONYMOUS. Pennsylvania and Lehigh Zinc Company.

Mining Magazine, vol. 2, pp. 99-100, New York, 1854.

Mentions Wetherill's process for making zinc white from Friedensville zinc ore. Praises the purity of the resultant product.

SMITH, J. LAWRENCE. Re-Examination of American Minerals, Part IV.

Am. Jour. Sci. and Arts (2d ser.), vol. 18, pp. 373-381, New Haven, 1854.

Reports lanthanite near South Bethlehem and gives analysis (pp. 378-379, 427).

WHITNEY, J. D. The Metallic Wealth of the United States.

510 pp., Philadelphia, 1854.

Gives a brief description of the Friedensville zinc mines to the close of 1853. The character of the ore and ore bodies are briefly described (pp. 351-352).

1855

ROEPPER, W. TH. Map of Bethlehem and the new town of Wetherill, Northampton County, Pa.

Scale: 1 inch = 400 feet. Press of P. S. Duval & Co., Philadelphia. 1855. Folded in cloth-bound cover.

In margin of map are views of the Pennsylvania and Lehigh Zinc Works, Upper (Calypso) Island, and first house in Bethlehem.

Map shows Dr. Oppelt's Hydropathic Institute (five buildings, where St. Luke's Hospital is now situated). The large spring of Upper (Calypso) Island is located along eastern shore.

1857

ANONYMOUS. Discovery of Zinc near Allentown.

Mining Mag., vol. 9, p. 182, New York, 1857.

Says that zinc ore similar to that in the Saucon Valley was discovered in the digging of a well in Allentown near the Lehigh River. This was probably an error as no further mention of it is known to have been published.

Genth, F. A. Contributions to Mineralogy—Lanthanite.

Am. Jour. Sci. and Arts (2d ser.), vol. 23, pp. 425-426, New Haven, 1857.

Dr. Genth acknowledges the gift of lanthanite from Friedensville. Analysis agrees with those of Wm. P. Blake and J. L. Smith.

Roberts, Solomon W., Chief Engineer. Map Showing the Route of the North Pennsylvania Rail Road from Philadelphia to Bethlehem with its Branches to Doylestown and Freemansburg and its connections with the Lehigh Valley Rail Road. January 1857. Road opened to the Lehigh River Jan. 1, 1857.

24″x48″. Scale: 1 inch = 2½ miles. Hist. Soc. of Pa.

A generalized map.

Silliman, Jr., B. Report on the Slate Quarries of the Lehigh Slate Company at Slatington, Lehigh County, Pennsylvania.

Pamphlet on Lehigh Slate Company, pp. 9-18, Philadelphia, 1857.

Describes the geology and the economics of the deposit.

Williams, W. A Geological and Topographical Map of Pennsylvania and New Jersey compiled from the official reports of the Geological Surveys, public and private. Published by Charles Descher, Philadelphia, 1857.

38″x52″. Scale 1 inch = 8 miles.

Geological formations are hand colored. Is based on Rogers' map. Bears statement that it was "submitted for correction to J. Peter Lesley . . . who constructed the maps and sections of the Geological Survey of Pennsylvania."

The entire Rittersville hill north of the Lehigh River is mapped as "Primal Sandstone; compact white sandstone, Formation I."

1858

Blake, William P. Lanthanite and allanite in Essex County, New Jersey.

Am. Jour. Sci. and Arts (2d ser.), vol. 26, pp. 245-246. New Haven, 1858.

Mention of lanthanite and allanite at Bethlehem (pp. 245, 246).

Rogers, Henry Darwin. The Geology of Pennsylvania.

Vol. 1, 586 pp., Vol. II, 1045 pp., geological map of the State, sections, etc. Philadelphia, 1858.

Many descriptions of geological features of Lehigh County. The following are the most important: Vol. I—geological section from Allentown to Coopersburg (pp. 100-101); Primal (Hardyston) quartzite (p. 196); basal limestone (p. 232); Kittatinny Valley limestones and shales (pp. 237-250); iron ores (pp. 236-266); Friedensville zinc mines (p. 236); structure of Blue Mountain (pp. 287-288). Geological section in back of volume. Volume II—Fossils (p. 692); minerals (pp. 710, 712); iron ores (pp. 723-727).

1859

Blodget, Lorin, Secretary. Twenty-sixth Annual Report of the Philadelphia Board of Trade.

226 pp., Philadelphia, 1859.

"In the Lehigh district most of the furnaces have continued in blast through the whole period of disaster to the trade generally, the demand for their iron, which is of superior quality, and has almost entirely displaced the Scotch pig for the use of founders, being such as to keep them steadily employed." (p. 113.) Annual anthracite furnace production of iron for three years in the Lehigh Valley, twenty out of twenty-four furnaces in operation: 1856—121,021 tons; 1857—113,299 tons; 1858—100,000 tons.

Lesley, J. P. The Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States.

772 pp., New York, 1859.

Contains numerous descriptions of the iron mines, furnaces and forges of Lehigh County.

1860

Eliot, Charles W. and Storer, Frank W. On the impurities of Commercial Zinc, with special Reference to the Residue insoluble in Dilute Acids to Sulphur and to Arsenic.

Memoirs Am. Acad. of Arts and Sci., new ser., vol. 8, pp. 57-96, Boston, 1860.

"The purest of all the zincs which we have analyzed is that manufactured at the Pennsylvania and Lehigh Zinc Works, Bethlehem, Pennsylvania." The analyses found no lead, a trace of cadmium and in one sample a little arsenic. The arsenic is believed to be present in the blende and pyrites but not in the calamine.

Henry, M. S. History of the Lehigh Valley.

436 pp., illustrations, Easton, 1860.

Numerous references to various geological features of Lehigh County; Lehigh Water Gap (pp. 308-310), iron mines and iron works (pp. 162-166), pottery and tile at Bethlehem (one half mile northwest of Bethlehem on Monocacy Creek (pp. 205, 214), zinc (pp. 236-238), Bower's Rock (Big or Mammoth Rock) (p. 277), springs (p. 277), water supply of Allentown (p. 284), of Catasauqua (p. 292), of Slatington (p. 306), Ironton iron mines (p. 301), slate (pp. 306-307), Lehigh Coal & Navigation Company and Lehigh Canal (pp. 375-394, 412-416).

1863

Anonymous (Possibly Thomas Scattergood).

Incidents of the Freshet in the Lehigh River, Sixth Month, 4th and 5th, 1862.

56 pp., Philadelphia, 1863. Pennsylvania Hist. Soc. and Moravian Archives.

Descriptions of flood conditions and damage done.

1864

Anonymous. Guide-Book of the Central Railroad of New Jersey and its connections through the coal-fields of Pennsylvania.

120 pp., New York, 1864.

Contains some interesting descriptions of the features and industries of the Lehigh Valley.

Percy, John. Metallurgy; Iron and Steel.

934 pp., London, 1864.

Brief description of the iron furnaces along the Lehigh River.

1865

Lesley, J. P. (No title) Comment on a lignite deposit in Franklin County, Pa.

Proceedings of the American Philosophical Society, vol. 9, pp. 463-480. Philadelphia, 1865.

Mentions that the Lehigh River below Allentown flows close to the southern edge of the limestone—up against the mountain (p. 470).

1869

Martin, John Hill. Historical Sketch of Bethlehem in Pennsylvania, with some account of the Moravian Church.

191 pp., Philadelphia. First edition 1869, second edition 1873.

Some account of the early industries of the region with descriptions of many geographic features.

Says that name of island (Calypso) in the river was properly catalpa from the number of catalpa trees there.

1871

Drinker, H. S. Mines and Works of the Lehigh Zinc Co.

Eng. & Min. Jour., vol. 12, pp. 129, 145-146, New York, 1871.

Am. Inst. Min. Met. Eng. Trans., vol. 2, pp. 67-75, Philadelphia, 1871.

Berg—und Huettenmaennische Zeitung, 1872, vol. 81, pp. 51-53, 61-62, Leipzig, 1872.

A description of the Friedensville zinc mines in which the ores and minerals are discussed. Particular attention is given to the methods of mining and utilization.

1872

ANONYMOUS. Friedensville Zinc Mines.

Eng. and Min. Jour., vol. 13, pp. 65-66, 73, 329, New York, 1872.

The speech of B. C. Webster at the ceremony of starting of the President (large pump). Statistics of production of zinc, depth of mine, capacity of pump, etc. (pp. 65-66). Editorial regarding the above address, and praising the management of the company (p. 73). Editorial on the pump, noting that it is performing well, and commending an ingenious device to regulate pumping to the amount of water present (p. 329).

HECKEWELDER, JOHN. Names which the Lenni Lennape or Delaware Indians gave to Rivers, Streams and Localities within the States of Pennsylvania, New Jersey, Maryland and Virginia with their significations.

Prepared from a manuscript of John Heckewelder, 1822, by William C. Reichel.

Moravian Hist. Soc. Trans., vol. 1, pp. 225-282, Nazareth, 1872.

Gives meaning of a number of Indian names applied to geographic features of Lehigh County.

C., L. (Probably Chamberlain, Lloyd). Guide-Book of the Lehigh Valley Railroad and its several branches and connections; with an account, descriptive and historical, of the Places Along their Route.

175 pp., Philadelphia, 1872.

Numerous facts concerning the physical features and industries of the Lehigh Valley.

REICHEL, WM. C. The Crown Inn, near Bethlehem, Pennsylvania, 1745.

162 pp., Philadelphia, 1872.

Account of the discovery of zinc ore at Friedensville by W. T. Roepper. A short history of the early attempts to work the mine and statistics of annual yield (pp. 141-144). Short descriptions of the Lehigh Mountain (Oppelt's) Springs Water Cure established in 1846, the Lehigh Zinc Company. Refers to Tinsley Jeter's brick yard a short distance southwest of Bishopthorpe. Gives a short description of the Lehigh Valley and North Pennsylvania railroads. Contains "Map, showing the condition of the 'Moravian Tract' on the South side of the Lehigh, opposite Bethlehem, at various times. Based upon Wm. Th. Roepper's Map of said Tract, drawn in 1854, and on drafts drawn by C. G. Reutter and others in 1753 and 1757 and by G. W. Golkowsky in 1760; and so prepared as to illustrate the history of the old Crown Inn."

1873

ANONYMOUS. Guide Book of the Lehigh Valley Railroad and its several branches and connections; with an account, descriptive and historical of the places along their route; including also a history of the company from its first organization, and interesting facts concerning the origin and growth of the coal and iron trade in the Lehigh and Wyoming regions.

186 pp., map, Philadelphia, 1873.

Contains brief descriptions of the mines and mineral industries of Lehigh and Northampton Counties.

MARTIN, JOHN HILL. Historical sketch of Bethlehem in Pennsylvania, with some account of the Moravian Church.

191 pp., Philadelphia. First edition, 1869; second edition, 1873.

1875

CLARK, ELLIS, Jr. The Subterranean Watercourses in the Magnesian Limestones of Lehigh County, Pa.

Eng. and Min. Jour., vol. 19, p. 433, New York, 1875.

An account of three springs in a line in Upper and Lower Macungie Townships. Believes that the streams are running in solution tunnels.

GENTH, F. A. Preliminary Report on the Mineralogy of Pennsylvania.

Pennsylvania Second Geol. Survey, Report B, 238 pp., Harrisburg, 1875.

Lists the following minerals, giving localities and descriptions, on the pages indicated by number: Allophane 107, aragonite 162-3, asbestos 69, calamine 106, calcite 154, damourite 126, dolomite 155, epsomite 149, fluorite 29, goslarite 149, graphite 8, greenockite 18-19, halloysite 122, kaolinite 120, lanthanite 165, lignite 232, limonite 49-50, marcasite 22, martite 35, melanterite 149, psilomelane 53, pyrite 20, pyroxene 66, quartz 57-58, quartz, fetid 59, 217, serpentine (pinite?) 115, siderite 159, smithsonite 161, sphalerite 15, turgite 47, wad 53-54.

McCreath, Andrew S. Report of Progress in the Laboratory of the Survey at Harrisburg.

Pennsylvania Second Geol. Survey, Report M, 105 pp., Harrisburg, 1875.

Contains analyses, most of which were also published elsewhere, of iron ores from Lehigh County (pp. 48-54, 89-90), four analyses of limestones (p. 76), damourite slate (p. 92), and two analyses of ocher (p. 92).

Prime, Frederick, Jr. On the Occurrence of the Brown Hematite Deposits of the Great Valley.

Am. Jour. Sci. and Arts, 3d ser., vol. 9, pp. 433-440, New Haven, 1875.

General discussion of iron ores of Great Valley, with special reference to lines of outcrop and cause of accumulation of ore. Mention of damourite-slates and theories of siderite replacement of limestone.

Prime, Frederick, Jr. Report of Progress on the Brown Hematite Ore Ranges of Lehigh County with a description of the mines lying between Emaus, Alburtis and Fogelsville.

Pennsylvania Second Geol. Survey, Report D, 73 pp., 8 plates, map, Harrisburg, 1875.

Describes briefly the geology of Lehigh County. Locates and gives brief descriptions of 98 iron mines between Emmaus, Alburtis and Fogelsville. In a note on the district by the State Geologist, J. P. Lesley, the following sentence appears: "What seems so smooth and regular a surface conceals one of the most contorted, twisted, fractured, cleft, plicated, complicated and even overturned set of subsoil rocks in the world" (p. 59).

Prime, Frederick, Jr. On the Occurrence of the Brown Hematite Deposits of the Great Valley.

Am. Inst. Min. Eng. Trans., vol. 3, pp. 410-422, Easton, 1875.

Describes the limonite ores of the Great Valley. Says they were probably formed by the oxidation of iron pyrites but not *in situ*.

Sheafer, P. W. and others. Historical Map of Pennsylvania.

26 pp., 1 col. map 23"x40". Hist. Soc. of Pennsylvania, Philadelphia, 1875.

Some early geographic names are given. Contains several errors.

1876

Anonymous. Pumping-Engine at the Lehigh Zinc Works, Friedensville, Penna.

Sci. Am. Sup., vol. 2, no. 32, pp. 502-4, 2 engravings. New York, 1876.

Complete description of the great engine at Friedensville, giving weights of the different parts. States that the engine is the largest in the world at the date of writing. Contains two excellent engravings of the engine.

Anonymous. Friedensville Zinc Mines.

Eng. and Min. Jour., vol. 22, pp. 216, 325-326. New York, 1876.

Reports that the Bethlehem Zinc Company has contracted for ore for five years from New Jersey Zinc Company. It will abandon its Friedensville mine. For some time it has cost $4 a ton to keep the mine water-free. 30,000,000 gallons of water per day pumped out (Sept. 30, 1876) (p. 216). An historical sketch of the Friedensville mines, with the measurements and history of the "President," the large Cornish pumping engine. The reasons for stoppage, and the qualities of the ore discussed (pp. 325-326).

Davis, F. A. New illustrated Atlas of Lehigh County, Pennsylvania.

72 + 37 pp., 50 maps. Reading Publishing Co., Reading, Pa., 1876.

72 pp. dealing with Lehigh Co. followed by 37 pp. of maps and descriptions of the Countries of the World.

Contains a complete series of township and borough maps on which iron ore mines and furnaces, quarries, brick yards, etc., are located.

Hall, Charles E. Notes on Glacial Action Visible along the Kittatinny or Blue Mountain, Carbon, Northampton and Monroe Counties, Pennsylvania.

Am. Philos. Soc. Proc., vol. 14, pp. 620-621, Philadelphia, 1876.

Evidence for the contention that the glaciation came from the north or northwest and proceeded farther to the southwest than the Lehigh Gap. Slates south of gap show direction of ice by drag indications.

Raymond, Rossiter W. Zinc.

Appleton's The New American Cyclopedia, vol. 16, pp. 635-649, New York, 1865. Later edition: vol. 16, pp. 816-825, New York, 1876.

Gives considerable information regarding the zinc deposits at Friedensville and the metallurgical processes.

1877

Anonymous. Zinkgewinnung in den Vereinigten Staaten von Amerika Berg—und Huettenmaennischen Zeitung, 1877, vol. 36, pp. 392-394, Leipzig, 1877.

Describes the process of smelting the Friedensville zinc ores at Bethlehem.

Fritts, Peter. History of Northampton County, Pennsylvania.

293 pp., Philadelphia, 1877.

Contains a description of the Friedensville zinc mines (pp. 211-212), Lechauweki Springs (p. 215).

1878

Allen, Charles. Two Hundred Tables of Elevations above tide-level in and around Pennsylvania.

Pennsylvania Second Geol. Survey, Report N, 279 pp., Harrisburg, 1878.

Gives elevation of many points along the following railroads—Lehigh Valley, Lehigh and Susquehanna (Central of New Jersey), Lehigh and Lackawanna (Lehigh and New England), East Pennsylvania (Reading), North Pennsylvania (Reading), Catasauqua and Fogelsville. Also levels of various places along the Delaware River.

Frazer, Persifor, Jr. Remarks on Prof. Prime's Paper (on the Paleozoic Rocks of Lehigh and Northampton Counties, Pa.).

Am. Philos. Soc. Proc., vol. 17, pp. 255-258, Philadelphia, 1878.

Remarks on origin of iron ores—results of chemical experiment. Relations of hydro-mica slate to limonite.

Groth, P. Die Mineraliensammlung der Kaiser-Wilhelms-Universitat, Strassburg.

271 pp., Strassburg, 1878.

Lists zincblende and greenockite from Friedensville and smithsonite and calamine from Bethlehem (Friedensville?), and gives brief descriptions of specimens. Describes crystallography of calamine from Friedensville and gives a drawing showing crystallographic forms.

Hall, Charles E. Catalogue of the Geological Museum, Part I.

Pennsylvania Second Geol. Survey, Report O, 217 pp., Harrisburg, 1878.

Contains a list of rock specimens collected in the Lehigh Gap and in the slate belt to the south (pp. 155-160).

Prime, Frederick, Jr. The Brown Hematite Deposits of the Siluro-Cambrian Limestones of Lehigh County lying between Shimersville, Millerstown, Schnecksville and the Lehigh River.

Pennsylvania Second Geol. Survey, Report DD, 99 pp., 5 maps and 5 plates. Harrisburg, 1878.

The various chapters of the report treat the topography, the Laurentian (pre-Cambrian), Potsdam (Hardyston), Damourite slates (Tomstown), magnesian limestones (Tomstown, Allentown, Beekmantown), Trenton limestone (Jacksonburg), Hudson River and Utica slates (Martinsburg) and Glacial deposits. On the map, 202 iron mines are located, most of which are briefly described. Four cement plants along the Lehigh River are described. Includes analyses of limestones and iron ores.

Prime, Frederick, Jr. On the Palaeozoic Rocks of Lehigh and Northampton Counties, Pennsylvania.

Am. Philos. Soc. Proc., vol. 17, pp. 248-254, 719. Philadelphia, 1878.

See next title.

Prime, Frederick, Jr. On the Discovery of Lower Silurian Fossils in Limestone associated with Hydro-mica Slates, and on other points in the Geology of Lehigh and Northampton Counties, Eastern Pennsylvania.

Am. Jour. Sci. and Arts, 3d ser., vol. 15, pp. 261-269, New Haven, 1878.

A very good description of the Potsdam (Hardyston) sandstones and quartzites, the hydro-mica slates (Tomstown), the No. II or Magnesian limestones (Allentown and Beekmantown), Trenton (Jacksonburg) limestones, and No. III (Martinsburg) slates. Discusses the characteristics and origin of the brown hematite (limonite) iron ores of the region. A few fossils found in Northampton County are described. This paper was first published in Proceedings of the American Philosophical Society under the title "On the Paleozoic Rocks of Lehigh and Northampton Counties, Pennsylvania."

1879

Clauder, H. J. Clauder's Year-Book and Home Almanac for 1879.

Pamphlet, 88 pp., Bethlehem, 1879.

Compilation of interesting information including descriptions of the Bethlehem Water Works, Lehigh Zinc Co., Bethlehem Iron Co., Calypso Island, etc.

McCreath, Andrew S. Second Report of Progress in the Laboratory of the Survey at Harrisburg.

Pennsylvania Second Geol. Survey, Report MM, 438 pp., Harrisburg, 1879.

Contains many analyses of products of Lehigh County, including 32 analyses of limonite (brown hematite) ores (pp. 213-218), clay associated with iron ore (p. 268), 3 limestones (p. 310).

Prime, Frederick, Jr. Moraines and Surface Drift Deposits of Northampton County, Pa.

Am. Philos. Soc. Proc., vol. 18, pp. 84-85, Philadelphia, 1879.

Absence of moraine immediately north of the Lehigh River. Drift prominent at West Bethlehem. Moraine in Saucon Valley. No trace of glacial action on South Mountain.

1880

Hall, Charles E. Catalogue of the Geological Museum, Part II.

Pennsylvania Second Geol. Survey, Report OO, 272 pp., Harrisburg, 1880.

Contains list of mineral and rock specimens and localities where collected in Lehigh County (pp. 30-31, 97-106).

1882

Chance, H. Martyn. Special Survey of the Lehigh Water Gap in 1875.

Pennsylvania Second Geol. Survey, Report G6, pp. 349-363. Harrisburg, 1882.

Describes strata exposed in the Lehigh Water Gap and gives section showing the succession and structure of the strata.

Genth, F. A. Contributions to Mineralogy.

Am. Philos. Soc. Proc., vol. 20, pp. 381-402, Philadelphia, 1882.

Describes and gives analysis of crystals of menaccanite associated with corundum crystals from Shimersville.

L(esley), J. P. Bake Oven Knob.

Foot-note in Pennsylvania Second Geol. Survey, Report G6, p. 63, Harrisburg, 1882.

Suggests that the Bake Oven was formed by water from the top of the glacial ice sheet pouring over the top of Blue Mountain.

Smith, Edgar F. and Thomas, N. Wiley. Corundum and Wavellite.

Am. Philos. Soc. Proc., vol. 20, pp. 230-231, Philadelphia, 1882.

Describes some corundum crystals found near Shimersville and wavellite near Macungie. An analysis of the latter is given.

1883

Clerc, F. L. The Mining and Metallurgy of Zinc in the United States.

Mineral Resources of the United States, 1882, U. S. Geol. Survey, pp. 361-365, Washington, 1883.

An excellent description of the Friedensville zinc mines.

Eng. and Min. Jour., vol. 36, pp. 148-149, New York, 1883.

Describes the Friedensville zinc deposits—history of operations, geology, origin by thermal (magmatic) waters, and reasons for closing mines.

Eyerman, John. Corundum in Lehigh County.

Eng. and Min. Jour., vol. 36, p. 220, 1883.

Describes the deposits near Old Zionsville.

Eyerman, John. The Friedensville Zinc Mines.

Eng. and Min. Jour., vol. 36, pp. 220, 374. 1883.

Gives short descriptions of the then current operations.

Lesley, J. P., Sanders, R. N., Chance, H. M., Prime, F. and Hall, C. E. The Geology of Lehigh and Northampton Counties.

Pensylvania Second Geol. Survey, Report D3, vol. 1, 283 pp., atlas of maps. Harrisburg, 1883.

Contains much information on Lehigh County including the following: eight analyses of iron ores (pp. XII-XIV), geographical description (pp. 7-12), streams in Lehigh County (pp. 18-22), slate region (pp. 31-35, 83-85), drift deposits (pp. 37-54), geological structures of the limestones (pp. 54-58), slate quarries (pp. 113-125), geological structures of slate region (pp. 134-136), slate cleavage, quarrying, statistics (pp. 136-148), slate belt along Lehigh River in 1875 (pp. 151-160), occasional references to Lehigh County localities in discussion of age, various members, character and analyses of limestones (pp. 161-190), Potsdam (Hardyston) sandstone (pp. 205-214), South Mountain gneiss and associated rocks and mines (pp. 215-241, 254-258).

Atlas contains a colored geological map (scale: 2 miles to 1 inch) of Lehigh and Northampton counties and part of Berks County, a topographical map of the Durham and Reading Hills (scale: 1600 feet to 1 inch) between Delaware and Schuylkill rivers in 18 sheets, a colored geological index map (scale: 2 miles to 1 inch), a colored geological and topographic map of southern Northampton County with part of Lehigh County (scale: 1600 feet to 1 inch) in 6 sheets showing location of iron mines.

Smith, Edgar F. Minerals from Lehigh County, Pa.

Am. Chem. Jour., vol. 5, pp. 272-279, Baltimore, 1883.

Describes the following minerals from Lehigh County with analyses of all except zircon: allophane, chloropal, corundum, fluorite, garnet, pyrolusite, stibnite, tourmaline, wavellite, zircon.

1884

d'Invilliers, E. V. Geology of Lehigh County.

History of the Counties of Lehigh and Carbon in the Commonwealth of Pennsylvania by Alfred Mathews and Austin N. Hungerford. Chapter XV, pp. 114-119, geologic map, Philadelphia, 1884.

A brief discussion of the geological formations mainly taken from the reports of the Second Geological Survey of Pennsylvania. Includes analyses of limestones and iron ores. The structure is described as follows: "The thickness of the limestone formation in Lehigh County is uncertain, for the apparently regular surface of the valley conceals a very troubled and irregular floor, from three to seven miles wide, so complicated and contorted as to defy accurate measurement or interpretation of dips.

"Its general structure is a series of tightly compressed rolls and basins, some regular, some overturned, twisted, and even snapped." (p. 116.)

Lacroix, Alfred. Sur quelques localites nouvelles de Greenockite.

Soc. Miner. de France, Bull., vol. 7, pp. 463-466, Paris, 1884.

Mentions a specimen of concretionary quartz containing blende, pyrite and greenockite from the Saucon Valley.

Lesley, J. P. Letter of Transmittal of Report on the Terminal Moraine in Pennsylvania and Western New York.

Pennsylvania Second Geol. Survey, Report of Progress Z, pp. v-xlix, Harrisburg, 1884.

Discusses formation of Bake Oven Knob, but advances no final explanation (pp. XLIV-XLV).

Lewis, H. Carvill. On supposed Glaciation in Pennsylvania, south of the Terminal Moraine.

Am. Jour. Sci., 3d ser., vol. 28, pp. 276-285, map. New Haven, 1884.

Examines the evidence that has been brought forth by others to indicate an extension of the glacial ice sheet beyond the "Terminal Moraine" passing through Pen Argyl and Belvidere and concludes that it is not valid. Believes that all the so-called glacial till beyond this point in Lehigh and Northampton counties was laid down by glacial streams. Briefly describes the Bake Oven on Blue Mountain and concludes that it is not of glacial origin.

Mathews, Alfred and Hungerford, Austin N. History of the Counties of Lehigh and Carbon in the Commonwealth of Pennsylvania.

802 pp., illustrated. Philadelphia, 1884.

Contains a chapter by E. V. d'Invilliers on the geology of Lehigh County with a geologic map (pp. 114-119). The iron ores and limestones are described briefly and several analyses given. In a history of the Friedensville zinc mines (pp. 439-440) Andrew K. Wittman is given credit for the discovery in 1845 and T. H. Roepper for bringing attention to the deposit, which resulted in the formation of mining companies. A sketch with photograph of Dr. Martin H. Boye, a Coopersburg geologist, is also included (pp. 440-442). Descriptions include the great floods of 1841 and 1862 (pp. 130 and 237); the water works of Allentown and sources of supply (pp. 136-139), of Catasauqua (pp. 247-249); the furnaces and iron industry of Allentown (pp. 155-161); of Catasauqua (pp. 237-243); of Lower Macungie Township (pp. 328-329); the Bake Oven and Bear Rocks, two miles to the west (p. 279). The derivations of many place names are given and the industries of different sections—mines, quarries, mills, etc. Iron ore of Upper Milford Township (pp. 345-346). Emaus and Hampton furnaces (pp. 391-392). Of Whitehall Township (pp. 501-505), ore mines of North Whitehall Township (pp. 522-523), Lehigh furnace of Washington Township (553). The Coplay Cement Works and Lehigh Valley Portland Cement Co. are described (pp. 505-507), and slate quarries (pp. 523-524, 553-555, 559).

1885

Anonymous. Friedensville Zinc Mines.

Eng. and Min. Jour., vol. 39, p. 94, New York, 1885.

The zinc mines at Friedensville, operated by Osgood and Company, New York, have shut down. (Feb. 7, 1885.)

Chance, H. M. Brown Hematite Ore Mining.

Eng. and Min. Jour., vol. 40, p. 57, New York, 1885.

An excellent description of methods employed in the mining of the limonite iron ores of the region, both by open cut and by shaft. The Zeigler mine located near the Berks-Lehigh county line is used as an illustration. A line drawing accompanies the article.

Lesley, J. P. A geological hand atlas of the sixty-seven counties of Pennsylvania.

Pennsylvania Second Geol. Survey, Report X, 112 pp., 62 colored maps, 1885.

Contains a geological map of Lehigh and Northampton counties, 6 miles to the inch and a brief description (pp. XLVIII-XLIX) of the geology and mineral resources of the county.

Smith, Edgar F. Mineralogical notes: Pectolite and Titanite.

Am. Chem. Jour., vol. 6, pp. 411-414, Baltimore, 1885.

Describes pectolite at Hosensack Station with analysis (p. 411), and titanite 2 miles from Hosensack Station (p. 412) with analysis.

1886

Anonymous. Friedensville Zinc Mines.

Eng. and Min. Jour., vol. 41, p. 423, New York, 1886.

Lehigh zinc spelter, Friedensville, has a world-wide reputation as the purest zinc in the world. It is the only zinc in the world that will not expand and make a cartridge stick in a gun while firing. Almost all European nations realized this and bought here, except England. The English have learned by bitter experience and have placed an order for zinc with the Bergenport Zinc Co.

Merriman, Mansfield, Wells, J. H., and Rowley, H. W. Map of Bethlehem, South Bethlehem and West Bethlehem compiled from recent surveys by J. H. Wells, C. E., and H. W. Rowley, M. E., under the supervision of

Mansfield Merriman, Professor of Civil Engineering in the Lehigh University. Scale: 1 inch = 400 feet. (Map folded in cover.)

Published by Edwin G. Close, Manager, Bethlehem, Pa., 1886.

In margin gives dates of several important events in the history of Bethlehem.

Pumpelly, Raphael, and others. Report on the Mining Industries of the United States.

Vol. 15, Tenth Census, 1025 pp., Washington, 1886.

Much data concerning iron mines of Lehigh County, including magnetite (p. 180), limonite ore analyses (pp. 182-185), carbonate (p. 202), and directory (pp. 966-968). Some notes on hydraulic cement (pp. 841, 848, 984) and on zinc (pp. 804-805, 979).

"Von Ben." Skizzen aus dem Lecha-Thale. Eine Sammlung von Nachrichten über die ersten Ansiedlungen der Weissen in dieser Gegend.

260 pp., Allentown, 1886.

Consists of 82 sketches published in the "Friedens-Bote," Allentown, between 1880 and 1886. Mainly historical sketches but with a number of articles containing geographic descriptions of parts of the Lehigh Valley, such as Blue Mountain, Bake Oven, "Bare" (Bear) Rocks. Derivation of various place names.

1887

Anonymous. Friedensville Zinc Mines.

Eng. and Min. Jour., vol. 43, p. 84, New York, 1887.

All mines in the vicinity of Friedensville have shut down because of the stoppage of the pump, "The President" (Jan. 29, 1887). Many ore pits for many miles around are now flooded.

Hill, Frank A. Lehigh River section continued from Lock 11, southward to the Blue Mountains.

Pennsylvania Second Geol. Survey, Ann. Report, 1886, Part IV, pp. 1372-1385, Harrisburg, 1887.

Gives section of the Oneida conglomerate in the Lehigh Water Gap (pp. 1378-1379).

Hotchkin, Rev. S. F. A Pocket Gazeteer of Pennsylvania.

174 pp., Philadelphia, Pa., 1887.

Contains a concise description of Lehigh County (pp. 103-106).

1888

McGee, W J Three Formations of the Middle Atlantic Slope.

Am. Jour. Sci., 3d ser., vol. 35, pp. 120-143, 328-330, 367-388, 448-466, New Haven, 1888.

Brief descriptions of the Quaternary deposits along the Delaware and Lehigh Rivers in the Lehigh Valley (pp. 379-381, 384, etc.).

1889

Davis, William Morris. The Rivers and Valleys of Pennsylvania.

Nat. Geog. Mag., vol. 1, pp. 183-253, 26 figs., Washington, 1889.

Reprinted in Geographical Essays, pp. 413-485, New York, 1909.

Describes the physiographic history of the Lehigh and Delaware Rivers. Concludes that "the Susquehanna, Schuylkill, Lehigh and Delaware are compound, composite and highly complex rivers, of repeated mature adjustment."

Eyerman, John. Notes on Geology and Mineralogy.

Acad. Nat. Sci. of Philadelphia, Proc., vol. 41, pp. 32-35, Philadelphia, 1889.

Gives an analysis of calamine from Friedensville.

Eyerman, John. The Mineralogy of Pennsylvania, Part I.

54 pp., Easton, 1889.

Minerals described from Lehigh County, some with analyses, are: allophane, andradite, calamine, chloropal, corundum, dolomite, fluorite, goethite, menaccanite, pectolite, psilomelane, pyrite, pyrolusite, siderite, stilbite, sulphur, tourmaline, wavellite, zircon.

LESLEY, J. P. A Dictionary of the Fossils of Pennsylvania.

Pennsylvania Second Geol. Survey, Report P4, 3 vols., 1283 pp., Harrisburg, 1889.

Figures and describes fossils found in Pennsylvania. *Scolithus linearis* (pp. 944-945) and *Maclurea magna* (pp. 369-370) are described from Lehigh County.

MERRILL, GEORGE P. Among the Pennsylvania Slate Quarries.

Sci. Am. Suppl., vol. 27, no. 681, p. 10874, New York, 1889.

Describes some of the slate quarries especially those of Slatington, quarrying methods, character of slate, etc.

WRIGHT, G. FREDERICK. The Ice Age in North America.

First edition, 622 pp., New York, 1889.

Fifth edition, 763 pp., Oberlin, 1911.

In several places refers to glacial phenomena in Lehigh County, especially at the Lehigh Gap.

1890

ANONYMOUS. Friedensville Zinc Mines.

Eng. and Min. Jour., vol. 50, p. 581, New York, 1890.

The zinc mines at Friedensville are being actively worked (Nov. 5, 1890). The large pump, the "President" is again pumping after several years idleness. It has nearly drained the mine since the latter part of September. Mining to start when the mine is dry.

1891

DAVIS, WILLIAM MORRIS. The Geological Dates of Origin of Certain Topographic Forms on the Atlantic Slope of the United States.

Geol. Soc. America Bull., vol. 2, pp. 545-586, Rochester, 1891.

In several places refers to the development of the peneplains of eastern Pennsylvania. Describes particularly the Cretaceous peneplain now preserved on the top of Blue Mountain, as well as the water gaps and wind gaps that cut through this ridge.

KIMBALL, JAMES P. Genesis of Iron Ores by Isomorphous and Pseudomorphous Replacement of Limestone, etc.

Am. Geologist, vol. 8, no. 6, pp. 352-376. Minneapolis, 1891.

Observation by Prime at Balliets' ore bank near Allentown. Notes alteration of limestone to iron carbonate particle by particle, or, "a pseudomorph by replacement."

1892

ANONYMOUS. Pleasant Places on the Reading Railroad. A Directory of Summer Resorts, Hotels, Boarding Houses on the Reading Railroad System.

64 pp., 1892.

Describes advantages and accommodations for summer tourists in Coopersburg and Centre Valley.

DAVIS, WILLIAM MORRIS. On the drainage of the Pennsylvania Appalachians. Boston Soc. Nat. Hist. Proc., vol. 25, pp. 418-420, Boston, 1892.

Believes that "the present courses of the streams have a very specialized relation to the structures that they flow over" but that some may be antecedent and not consequent streams.

LESLEY, J. P., D'INVILLIERS, E. V., SMITH, A. D. W., and LYMAN, B. S. A Summary Description of the Geology of Pennsylvania.

Pennsylvania Second Geol. Survey, Summary Final Report.

3 vols., 2638 pp., with atlas of maps, Harrisburg, 1892-1895.

A general summary of information obtained during the progress of the Second Geological Survey of Pennsylvania. Many references to Lehigh County, especially the following: Archean (pp. 74-75), South Mountain (p. 144), iron mines (pp. 231-235, 254-255, 341-350, 430), Great Valley (pp. 270-286), limestones (pp. 301-308), cement (pp. 337-340), zinc mine (pp. 436-443), slate (pp. 574-587, 604-609), Lehigh water gap (pp. 633-636, 674-675), argument against erosion interval at top of slate (Martinsburg) (pp. 710-711), no metallic wealth in North (Blue)

Mountain (pp. 712-713). The geological map of Bucks and Montgomery counties contained in the atlas shows part of Lehigh County in the vicinity of Coopersburg in which the mapping is partly incorrect according to present views.

Salisbury, R. D. Certain Extra-Morainic Drift Phenomena of New Jersey. Geol. Soc. America Bull., vol. 3, pp. 173-182, Rochester, 1892.

Describes glacial boulders south of the Lehigh River (p. 179).

1893

Barrell, Joseph. A preliminary survey of the South Mountains, with the valleys adjacent, in the vicinity of Lehigh University in respect to glaciation.

Unpublished thesis, 103 pp., maps, plates, 1893. Lehigh University Library.

Many observations in Saucon Valley.

Berlin, A. F. Lehigh Island and Its Relics.

The Archæologist, vol. 1, pp. 13-16, Waterloo, Indiana, 1893.

Describes many Indian objects found on the island at Allentown.

Foerste, Aug. F. New fossil localities in the early Paleozoics of Pennsylvania, New Jersey and Vermont, with remarks on the close similarity of the lithologic features of these Paleozoics.

Am. Jour. Sci., 3d ser., vol. 46, pp. 435-444, 1893.

Brief descriptions of the lithologic and paleontologic features of the Cambrian (Hardyston) sandstones and Cambro-Ordovician limestones along or near the Lehigh River.

Kemp, J. F. Ore Deposits of the United States and Canada.

First edition, 302 pp., New York, 1893. Second edition, New York, 1895. Third edition, 481 pp., New York, 1900.

Mentions the occurrence of zinc ore at Friedensville, describing the deposit, and sketching its history briefly. Notes the high grade of spelter produced.

Mercer, Henry C. Prehistoric Jasper Quarries in the Lehigh Hills.

The Archæologist, vol. 1, pp. 1-5, Waterloo, Indiana, 1893.

Describes the jasper quarries near Vera Cruz and Macungie.

Mercer, H. C. Prehistoric Jasper Mines in the Lehigh Hills.

Popular Sci. Monthly, vol. 43, pp. 662-673, 9 figs., New York, 1893.

Describes particularly the Indian jasper quarries of Vera Cruz and Macungie.

Williams, Edward H., Jr. Glaciation in Pennsylvania.

Science, vol. 21, p. 343, New York, 1893.

Presents evidence to prove that a glacial ice sheet actually passed over South Mountain in the vicinity of Lehigh University.

1894

Mercer, H. C. Indian Jasper Mines in the Lehigh Hills.

American Anthropologist, vol. 7, pp. 80-92, map, plate, 2 figures. 1894.

An excellent description of old Indian jasper diggings near Limeport, Vera Cruz, and Macungie.

Penrose, R. A. F., Jr. The Superficial Alteration of Ore Deposits.

Jour. Geology, vol. II, pp. 288-317, Chicago, 1894.

Brief mention (p. 304) of iron deposits in the Cambrian, Lower Silurian, and Carboniferous rocks of the Appalachian Valley. Many can be shown to be due to superficial replacement of limestones, or even of shales.

Williams, Edward H., Jr. Extramorainic Drift between the Delaware and Schuylkill.

Geol. Soc. America Bull., vol. 5, pp. 281-296, map, Rochester, 1894.

Moraine behind the Lehigh Gap (p. 281). Reference to Report D3, vol. I, 1883, p. 37, re drift on limestone plain. Sketch map showing extramoraine fringe in Lehigh and Northampton Counties. Discussion of river systems, rocks, glacial deposits, Glacial Lake Packer, Packer clay, gravels, drumlins, kames, eskers.

Summary of age of till (p. 293). Post glacial interval short. Moraine formed when ice withdrew from the Lehigh—it and extra-morainic deposits contemporaneous and recent.

Williams, Edward H., Jr. The Age of the Extra-Moraine Fringe in Eastern Pennsylvania.

Am. Jour. Sci., 3d ser., vol. 47, pp. 33-36, New Haven, 1894.

Presents evidence in support of the view that "as far as Eastern Pennsylvania is concerned, the extra-moraine fringe is of extremely recent origin and, as it antedates the formation of the great moraine, all glacial deposits in this region are of extreme recency."

1895

Lyman, Benjamin Smith. Report on the New Red of Bucks and Montgomery Counties.

Pennsylvania Second Geol. Survey, Summary Final Report, vol. 3, part 2, pp. 2589-2638, Harrisburg, 1895. Accompanying map, 1893.

Flint Hill is described as "formerly supposed to be made up of New Red rocks . . . but it seems rather to consist of the quartzitic early Paleozoic and sandrock called Chikis (Hardyston of present classification) Sandstone, or No. I, which is here more or less reddish and covers the ground with a reddish hard gritty sand similar in color but different in character from the New Red materials" (p. 2602). This idea is no longer held.

Williams, Edward H., Jr. Notes on the Southern Ice Limit in Eastern Pennsylvania.

Am. Jour. Sci., 3d ser., vol. 49, pp. 174-185, map. New Haven, 1895.

Describes briefly glacial deposits of the Lehigh Valley and gives map showing their extent.

1896

Walcott, Charles Doolittle. The Cambrian Rocks of Pennsylvania.

U. S. Geol. Survey Bull. 134, 43 pp., 15 plates. Washington, 1896.

Contains brief descriptions of the Cambrian strata of the Lehigh Valley.

1897

Williams, Edward H., Jr. Greenland glaciers.

Science, new ser., vol. 5, p. 448, New York, 1897.

Phenomena of ice action at Bethlehem cited to prove that "the finding of angular ridges or peaks . . . is . . . no sign of the absence of ice from the locality."

1898

Eben, Carl Theo. Gottlieb Mittelberger's Journey to Pennsylvania in the year 1750 and Return to Germany in the year 1754, containing not only a description of the country according to its present condition, but also a detailed account of the sad and unfortunate circumstances of most of the Germans that have emigrated, or are emigrating to that country.

129 pp., Phila. 1898. English translation of German publication, 1756.

Contains several brief references to the region now embraced in Lehigh County. Describes plants, wild animals, birds, Indians, etc. Black snakes in the Blue Mountains (evidently what is now known as South Mountain or the Reading Hills) are said to be 12 to 15 feet long and rattlesnakes "more than 18 feet long and as thick as a hay pole." The "Blue Mountains" range "begins at the Delaware River, and passes to the left across the country, and reaches as far as the great river Ohio."

"In the Blue Mountains various rich ores have been found which are kept concealed as yet as much as possible; this ore consists for the most part in copper, sulphur and iron and promises a rich yield." (pp. 100-101.)

Heilprin, Angelo. The Earth and Its Story.

267 pp., Boston, 1898.

The Delaware Water Gap and the Lehigh Gap are briefly described (p. 58).

Merriman, Mansfield. The Slate Regions of Pennsylvania.

Stone for July, 1898. 16 pp., 5 figures. Chicago, 1898.

Short descriptions of the slates and the slate industry of Lehigh County.

Williams, Edward H., Jr. Notes on Kansan Drift in Pennsylvania.

Am. Philos. Soc. Proc., vol. 37, pp. 84-87, Philadelphia, 1898.

Brief statement that "the Lehigh and its tributaries acquired their present level in pre-Kansan times."

1899

Borhek, Henry T. An attempt to determine the preglacial course of the Manokisy (Monocacy).

Unpublished student thesis, 34 pp., 1 map, 1 chart, 1899, Lehigh University Library.

Presents evidence to show that Monocacy Creek at one time turned to the southwest in the northwest part of Bethlehem, cutting a channel in what is now West Bethlehem, and joined a westward flowing tributary of Lehigh River which then flowed southwestward into Perkiomen Creek.

1900

Anonymous. The Development and Future Prospects of Portland Cement Manufacture in America.

Engineering News and American Railway Journal, vol. 44, pp. 60-62, 1900.

An editorial discussing the history of portland cement.

Hopkins, Thomas C. The Clays of the Great Valley and South Mountain Areas in Pennsylvania.

Pennsylvania State College Annual Report, 1899-1900, Appendix, 45 pp., Harrisburg, 1900.

Describes a few occurrences of white clay in Lehigh County (pp. 24-25), red brick clay plants of Bethlehem and Allentown (pp. 30-35), and a vitrified paving brick plant at Guth's Station (pp. 36-39). Mentions iron ores, cement, slate and zinc of Lehigh County.

Hopkins, T. C. Cambro-Silurian Limonite Ores of Pennsylvania.

Geol. Soc. America Bull., vol. 11, pp. 475-502, pl. 50, Rochester, 1900.

An excellent account of the occurrence, characteristics and origin of the limonite ores of the State with occasional mention of those of Lehigh County. Includes an annotated bibliography.

Hopkins, T. C. The White Clays of Southeastern Penna.

Eng. and Min. Jour., vol. 70, p. 131, New York, 1900.

Brief reference to white clay in some of the iron ore pits of Lehigh County.

Thomas, Samuel. Reminiscences of the Early Anthracite-Iron Industry.

Trans. Amer. Inst. Min. Eng., vol. 29, pp. 901-928, 10 figs., New York, 1900.

Descriptions of the early iron furnaces of the region.

1901

Hopkins, T. C. Limonite Ores of Pennsylvabnia.

Mines and Minerals, vol. 21, pp. 97-100, 1900. Scranton, 1901.

Gives list by counties of limonite ore pits, idle and operated, of the Cambro-Ordovician areas of Pennsylvania. Lehigh County is easily first on the list.

1902

Hauser, James J. A History of Lehigh County, Second edition.
128 pp., Allentown, 1902.

An earlier edition was published in 1901.

Contains much material of geographic interest in addition to historical data.

Williams, Edward H., Jr. Kansas Glaciation and its Effect on the River System of Northern Pennsylvania.

Wyoming Hist. and Geol. Soc. Proc. and Coll., vol. 7, pp. 21-28, 11 figures, Wilkes-Barre, 1902.

Says the Lehigh originally flowed southward from Allentown through Leipert's (Leiberts) Gap and into the Perkiomen "the portion of the stream between Allentown

and Easton being a case of piracy on the part of the Delaware, cutting more rapidly than the Lehigh and forcing the low col about Glendon westward till the Lehigh drainage level was reached." Describes a thickness of 165 feet of glacial deposits in West Bethlehem resting on the pre-Cambrian crystalline rocks. Believes that the "Monokisy (Monocacy) flowed westward into the Lehigh and passed under West Bethlehem ridge on a line running through the intersection of 12th avenue and Broad street."

1903

Campbell, Marius R. Geographic Development of Northern Pennsylvania and Southern New York.

Geol. Soc. America Bull., vol. 14, pp. 277-296, New York, 1903.

Describes the Harrisburg and Somerville peneplanes as developed in Lehigh County. Says they are probably of early Tertiary age.

Dale, T. Nelson. The Slate Industry at Slatington, Pa., and Martinsburg, W. Va.

U. S. Geol. Survey Bull. 213, pp. 361-364, Washington, 1903.

Short account of the physical characteristics, mineral composition and structure of the slate of the Slatington region.

Levering, Joseph Mortimer. A History of Bethlehem, Pennsylvania, 1741-1892.

809 pp., 86 plates. Bethlehem, 1903.

Contains much geographic information and descriptions of the industries of the Lehigh Valley.

Peck, Frederick B. Basal Conglomerate in Lehigh and Northampton Counties, Pennsylvania.

Geol. Soc. America Bull., vol. 14, pp. 518-521, New York, 1903.

Abstract, Science, new ser., vol. 17, p. 291, New York, 1903; Jour. Geology, vol. 11, pp. 108-109, Chicago, 1903; Eng. and Min. Jour., vol. 75, p. 154, New York, 1903.

A short description of the distribution and characteristics of the Cambrian quartzites, sandstones and conglomerates composing the Hardyston formation as developed in Lehigh and Northampton Counties.

1904

Anonymous. The Thomas Iron Company, 1854-1904.

98 pp., illustrated, New York, 1904.

Contains much historical matter concerning the iron industry of the Lehigh Valley.

Eckel, Edwin C. Cement-rock deposits of the Lehigh District of Pennsylvania and New Jersey.

U. S. Geol. Survey Bull. 225, pp. 448, 456, Washington, 1904.

A short description of the geology of the Lehigh cement district with several analyses of cement rock.

Garrison, F. Lynwood. The Genesis of Limonite Ores in the Appalachians. Eng. and Min. Jour., vol. 78, pp. 470-471, New York, 1904.

Discussion of origin of limonite ores with brief mention of Lehigh County.

Peck, F. B. The Cement Belt in Lehigh and Northampton Counties of Pennsylvania.

Mines and Minerals, map, 6 figures, vol. 25, pp. 53-57, Scranton, 1904.

Lists and describes the following formations of the Lehigh Valley: Pre-Cambrian crystalline rocks, Cambrian basal conglomerate, Trenton limestone, cement rock, Hudson River slate, Oneida and Medina sandstone. Gives several chemical analyses.

1905

Jordan, John W., Green, Edgar Moore, and Ettinger, George T. Historic Homes and Institutions and Genealogical and Personal Memoirs of the Lehigh Valley, Pennsylvania.

2 vols., 516 pp. and 528 pp., New York, 1905.

Contains biographic sketches of many men who were concerned in the development of the mineral resources of the Lehigh Valley.

1906

DALE, T. NELSON. Slate Deposits and Slate Industry of the United States. U. S. Geol. Survey Bull. 275, 154 pp., 25 plates, 15 figures, Washington, 1906.

Discusses origin, composition and structure of slate and describes the slate deposits. The individual quarries of Lehigh County and the microscopic characteristics of the slate obtained from them are described (pp. 81-85). Contains tests on slates by Mansfield Merriman.

HAUSER, JAMES J. Northampton Town and Allentown.

The Pennsylvania-German, vol. 7, pp. 244-252, Lebanon, 1906.

In praise of Schantz's Spring, five miles west of Allentown, the author writes as follows: "In this marvelous spring, which is supposed to be connected by a subterranean channel with Lake Erie, the water pours from an opening thee (three) feet in diameter and apparently bottomless".

TOWER, WALTER S. Regional and Economic Geography of Pennsylvania, Part I, Physiography.

69 pp., Philadelphia, 1906. Reprinted from Bull. Geog. Soc. Philadelphia, vol. 4, January-July, 1906.

In the general descriptions of the physiographic regions of the State, many references are made to the features in Lehigh County.

1908

PECK, FREDERICK B. Geology of the Cement Belt in Lehigh and Northampton Counties, Pa., with brief history of the origin and growth of the industry and a description of the methods of manufacture.

Econ. Geol., vol. 3, pp. 37-76, Lancaster, 1908.

A discussion of the stratigraphy of the region with especial descriptions and analyses of the limestones used in the manufacture of portland cement.

SCHULER, HENRY A. The Hampton Furnace.

Lehigh County Hist. Soc. Proc., vol. 1, pp. 141-152. Allentown, 1908.

Gives a history of Hampton (Mary Ann) Furnace, which was located on Perkiomen Creek, Upper Milford Township, Lehigh County. It was built in 1809 and was operated (not continuously apparently) until 1867 or 1868. The iron ore, limestone and charcoal came from the immediate vicinity.

1909

CHANCE, H. M. A New Theory of the Genesis of Brown Hematite Ores; and a New Source of Sulphur Supply.

Am. Inst. Min. Eng. Trans., vol. 39, pp. 522-539, 1909.

Discussion by Charles Catlett in same volume, pp. 916-920.

Describes the occurrence of limonite ores of the Great Valley with specific references to some mines in Lehigh County. Claims the ore bodies are gossan deposits. States that pyrite deposits of commercial importance probably underlie the limonite ores.

GRABAU, A. W. Physical and Faunal Evolution of North America during Ordovicic, Siluric and Early Devonic Time.

Jour. Geology, vol. 17, pp. 209-252, Chicago, 1909.

Mentions the Shawangunk formation thinning southward from 700 feet at the Delaware Water Gap to 400 feet at the Lehigh Gap. Indicates non-marine overlap.

GRABAU, A. W. The Medina and Shawangunk Problems in Pennsylvania.

Science, new ser., vol. 30, p. 415, New York, 1909.

The Shawangunk strata of Blue Mountain are referred to the Salina formation.

WHERRY, E. T. The Early Paleozoic of the Lehigh Valley District, Pennsylvania.

Science, new ser., vol. 30, p. 416, New York, 1909.

Announces the division of the Cambro-Ordovician limestones of the Lehigh Valley into five formations. Erroneously reports two areas of Shawangunk conglomerate "some twenty miles south of the main exposure in the Blue Ridge."

1910

HALBERSTADT, BAIRD. The Principal Limestone Deposits of Pennsylvania and Their Adaptability to the Manufacture of Portland Cement.

Fifteenth Annual Report of the Pennsylvania Department of Agriculture for 1909, pp. 545-555, Harrisburg, 1910.

Briefly describes the Lehigh cement district.

MERRILL, GEORGE P. Stones for Building and Decoration.

3d ed., 551 pp., 33 plates, 24 figures, New York, 1910. Earlier editions, 1891 and 1897.

Contains brief descriptions of the slates of the Lehigh Valley (pp. 194-195, 400-401, 484-488).

STODDARD, JESSE C., and CALLEN, ALFRED C. Ocher Deposits of Eastern Pennsylvania.

U. S. Geol. Survey Bull. 430, pp. 424-439, 2 figures. Washington, 1910.

Discusses the origin of ocher and describes deposits near Alburtis and Breinigsville.

1911

EYERMAN, JOHN. The Mineralogy of of Pennsylvania, Part II.

25 pp., privately published, Easton, 1911.

Gives an analysis of calamine from Friedensville, descriptions of allophane and fluorite from Ironton, and an excellent photograph and brief description of the Ueberroth zinc mine at Friedensville.

MILLER, BENJAMIN L. Paint Shales of Pennsylvania.

U. S. Geol. Survey Bull. 470, pp. 485-496, Washington, 1911.

Brief statement of the use of Martinsburg slates of Lehigh County for black paint.

MILLER, BENJAMIN L. The Mineral Pigments of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Report 4, 101 pp., 29 plates, 9 figures, Harrisburg, 1911.

Short descriptions of the pre-Cambrian, Cambrian, and Ordovician formations of Lehigh County. Some ocher and black slate deposits of the county are described.

PECK, FREDERICK B. Preliminary Report on the Talc and Serpentine of Northampton County and the Portland Cement Materials of the Lehigh District.

Pennsylvania Topog. and Geol. Survey Report 5, 65 pp., 17 plates, 9 figures, Harrisburg, 1911.

The Cambrian, Ordovician, and early Silurian strata of the Lehigh Valley are described, also the cement industry of the region.

SCHÖEF, JOHANN DAVID. Travels in the Confederation (1783-1784). Translation of "Reise durch einige der mittlern und sudlichen vereinigten nord amerikanischen staatenunternomme in den Jahren 1783 und 1784."

Two parts, Erlangen, 1788. Translated and edited by Alfred J. Morrison. Two vols., 426 and 324 pp., Philadelphia, 1911.

The author spent some time at Bethlehem and Nazareth and has described the topography, geology of the soils, and industries of the inhabitants of these as well as the areas crossed by him in journeyiug to the Wind Gap. Describes streams, springs, sink holes, rocks, etc. He speaks of the "Leheigh River" as "a soft, clear, pure stream flowing over a rocky bottom." Says the limestone valley was covered with forests consisting "for the greater part of white, red, and black oak" and the slate hills covered with the "bush oak" seldom over three to four feet in height.

ULRICH, E. O. Revision of the Paleozoic Systems.

Geol. Soc. America Bull., vol. 22, pp. 281-680, New York, 1911.

Contains references to the Cambrian and Ordovician strata of the Lehigh Valley. The Upper Cambrian limestones are considered to be Ozarkian (pp. 644-646, 655, 665-666, etc.).

1912

GLACE, WILLIAM H. A Narrative of Hydraulic Cement Mined in the Lehigh Valley.

16 pp., 3 plates, Catasauqua, 1912.

A sketch of the beginning of cement manufacture in the Lehigh Valley.

Miller, Benjamin LeRoy. The Geology of the Graphite Deposits of Pennsylvania.

Econ Geol., vol. 7, pp. 762-777, New Haven, 1912.

Brief mention of Lehigh County graphite occurrences.

Miller, Benjamin L. Graphite Deposits of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Report 6, 147 pp., 18 plates, Harrisburg, 1912.

Localities in Lehigh County where graphite occurs are described, especially near Vera Cruz and Emmaus where graphite mines have been operated.

Wherry, Edgar T. The Triassic of Pennsylvania.

Acad. Nat. Sci. Philadelphia Proc., vol. 64, p. 156, Philadelphia, May, 1912.

Brief abstract of article later published in full in Proc. of the Acad. Nat. Sci. of Philadelphia, vol. 65, pp. 114-125, Philadelphia, March 1913.

1913

Barrell, Joseph. Piedmont terraces of the northern Appalachian and their origin.

Abstract, Geol. Soc. Am. Bull., vol. 24, pp. 688-690, 1913.

Post-Jurassic history of the northern Appalachians.

Abstract and discussion, Geol. Soc. Am. Bull., vol. 24, pp. 690-696, 1913.

In these two papers Barrell suggested the formation of the terraces (peneplanes) of the Appalachians by marine planation instead of fluvial erosion.

Bliss, Eleanora F. Glaucophane from Eastern Pennsylvania.

Am. Mus. Nat. Hist., Bull., vol. 32, pp. 517-526, New York, 1913.

Describes a blue mineral occurring in pre-Cambrian rocks of Lehigh and other counties which is identified as glaucophane. (Later called crocidolite by Wherry, 1922.)

Brown, Amos P., and Ehrenfeld, Frederick. Minerals of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Report 9, 160 pp., 10 plates, 1 figure, Harrisburg, 1913.

Describes the important minerals and rocks of Pennsylvania and gives the principal localities where they occur. Many localities in Lehigh County are cited.

Coons, A. T. Slate.

Mineral Resources U. S., 1912, pt. 2, pp. 675-692, Washington, 1913.

Includes statistics and a general discussion of the economics of the slate industry and methods of working. Frequent references to the slate of Lehigh County.

Dale, T. Nelson. The Commercial Qualities of the Slates of the United States, and Their Localities.

Mineral Resources U. S., 1912, pt. 2, pp. 693-707, Washington, 1913.

Describes the distribution and characteristics of the "soft vein" and "hard vein" slates of Lehigh and Northampton Counties with brief descriptions of some quarries.

Eckel, Edwin C. Portland Cement Materials and Industry in the United States; with contributions by E. F. Burchard and others.

U. S. Geol. Survey Bull. 522, 401 pp., maps, Washington, 1913.

Contains a short chapter on the cement materials and cement industry of the Lehigh District (pp. 310-322) with a generalized map of the region.

Frear, William, and Erb, E. S. The Lime Resources of Pennsylvania.

Annual Report of Pennsylvania State College for 1911-1912, pp. 272-440, Harrisburg, 1913.

Gives analyses of limestones and dolomites from eleven different quarries in Lehigh County (pp. 313-318).

Frear, William. Pennsylvania Limestone and Lime Supplies.

Pennsylvania State College Agr. Exp. Sta. Bull. 127, pp. 71-106, State College, 1913.

Contains 25 analyses of Lehigh County limestones (pp. 91-92).

GRABAU, AMADEUS W. Early Paleozoic Delta Deposits of North America.

Geol. Soc. America Bull., vol. 24, pp. 399-528, New York, 1913.

Discusses the origin and correlation of various Paleozoic formations represented in Lehigh County, particularly the Martinsburg and Shawangunk and mentions specifically a few localities within the county.

HICE, RICHARD R. Mineral Production of Pennsylvania for 1911.

Pennsylvania Topog. and Geol. Survey Report 8, 138 pp., 51 pp., 84 pp., Harrisburg, 1913.

Statistics of mineral production with lists of producers.

WHERRY, EDGAR T. North Border Relations of the Triassic in Pennsylvania.

Acad. Nat. Sci. Philadelphia Proc., vol. 65, pp. 114-125, map, Philadelphia, 1913.

Describes the conglomerates occurring in the north border of the Triassic in the extreme southeast portion of Lehigh County. Thinks that the cobbles of the conglomerate were transported by floating ice in streams coming from the Appalachian Mountains to the north.

1914

DALE, T. NELSON, and others. Slate in the United States.

U. S. Geol. Survey Bull. 586, 220 pp., 26 plates, 18 figures, Washington, 1914.

Discusses origin, composition, texture, structure, and economic geology of slate. Lehigh County quarries are described (pp. 104-108).

HICE, RICHARD R. Mineral Production of Pennsylvania in 1912.

Pennsylvania Topog. and Geol. Survey, Biennial Report for the two years ending June 1, 1914, pp. 79-232, Harrisburg, 1914.

Statistics of the mineral production of the county, with short descriptions of each product.

MILLER, BENJAMIN L. Anniversary History of Lehigh County, Pennsylvania, Chapter 1, Geology, pp. 1-14, Allentown, 1914.

A non-technical account of the geology and mineral resources of Lehigh County.

ROBERTS, CHARLES RHOADS; STOUDT, JOHN BAER; KRICK, THOMAS H.; and DIETRICH, WILLIAM J. History of Lehigh County, Pennsylvania, three volumes.

Vol. 1, 1101 pp., Allentown, 1914.

Contains many descriptions of the geological features and mineral resources of Lehigh County (see separate title for chapter on Geology by B. L. Miller). Some of the most important are the following: jasper quarries (p. 28), floods of the Lehigh River (pp. 428-430, 472-474, 601-602), springs (pp. 431-432, 865-866, 902), water works and artesian wells (pp. 588-590, 658, 664, 677, 737, 821, 1011-1012), iron ores and iron works (pp. 558-559, 575-579, 593-594, 633, 668, 671, 696, 767, 783, 785, 788, 853-854, 897-898, 956-957, 1007-1010, 1018, 1038-1039), brick works (pp. 574-575, 578, 634, 712, 731, 783, 888, 1071-1072), stone quarries, lime, cement (pp. 584, 712, 798, 801, 855, 862, 911-913, 1011, 1015, 1064-1069), slate (pp. 674-676, 686-687, 820, 827-828, 854-855, 962-965, 1054-1056), corundum (p. 785), zinc (pp. 938-940), sand (p. 864), pottery (p. 80), Bake Oven Knob (p. 737).

SALISBURY, S. H., Jr., and BECK, GEORGE C. A Study of the Dolomitic Limestones of the Allentown Quadrangle.

Jour. Indus. and Chem. Eng., vol. 6, no. 10, pp. 837-851, New York, 1914.

A chemical investigation of some dolomitic limestones of the Lehigh Valley. Many analyses and discussions of origin of the dolomites.

1915

CARTER, W. T., Jr., and KERR, J. A. Soil Survey of Lehigh County, Pennsylvania.

U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1912, pp. 109-152, map, Washington, 1915.

A description of the soil types represented within the county and their adaptabilities. Briefly describes the geology and the industries of the region.

Hice, Richard R. The Mineral Production of Pennsylvania for the year 1913.

Pennsylvania Topog. and Geol. Survey, Report 11, 108 pp., Harrisburg, 1915.

Statistics of the mineral production of the county with short descriptions of each product.

Shaw, Charles F., McKee, J. M., and Ross, W. G. Reconnaissance Soil Survey of Southeastern Pennsylvania.

U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1912, pp. 247-340, map, Washington, 1915.

Describes the soil types in 19 counties of the southeastern part of Pennsylvania, including Lehigh County, and their adaptabilities. Map shows distribution of the various soils. The history and development of the region is described. Many references to the geological features.

1916

Schuchert, Charles. Silurian Formations of Southeastern New York, New Jersey and Pennsylvania.

Geol. Soc. America Bull., vol. 27, pp. 531, 554, New York, 1916.

Discusses the correlation of the Shawangunk formation and concludes that it is of Medina-Clinton-Niagaran age. The section at Lehigh Gap is described.

Water Supply Commission of Pennsylvania. Water Resources Inventory Report.

Part V, Precipitation, 205 pp., 1916.

Gives precipitation data for Allentown, Bethlehem, Center Valley, Coopersburg, Dillingersville, Egypt, Lynnport, North Whitehall, Whitehall, and Zionsville.

Wherry, Edgar T. Two New Fossil Plants from Triassic of Pennsylvania.

U. S. Nat. Mus. Proc., vol. 51, pp. 327-329, 2 plates,, Washington, 1916.

Describes a new plant, *Brunswickia dubia,* from the Triassic, three-fourths mile northeast of Coopersburg.

1917

Anderson, John A. Navigation on the Delaware and Lehigh Rivers.

Bucks County Hist. Soc., vol. 4, pp. 282-312, Easton, 1917.

Describes the utilization of the Lehigh and Delaware Rivers before the advent of the railroad.

Barrell, Joseph. Rhythms and the Measurements of Geologic Time.

Geol. Soc. America Bull., vol. 28, pp. 745-904, 1917.

In his discussion of rhythms of sedimentation the author uses illustrations of the ribboned slates and the *Cryptozoon* limestones of Lehigh County (pp. 803-806).

Jonas, Anna I. Pre-Cambrian and Triassic Diabase in Eastern Pennsylvania.

American Mus. Nat. Hist. Bull., vol. 37, pp. 173-181, map. New York, 1917.

Describes the crystalline rocks of that portion of Lehigh County embraced within the Boyertown and Quakertown quadrangles.

Oerter, Albert L. Tile Stoves of the Moravians at Bethlehem, Pa.

Bucks County Hist. Soc., vol. 4, pp. 479-481, Easton, 1917.

Brief description of the making of pottery, tile and clay pipes of local clay at Bethlehem between 1743 and 1793.

Rapp, R. Francis. Lehigh and Delaware Division Canal Notes.

Bucks County Hist. Soc., vol. 4, pp. 600-606, Easton, 1917.

Some interesting facts concerning navigation on the Lehigh Canal and Lehigh River and descriptions of floods of the Lehigh River.

Schrader, Frank C., Stone, Ralph W., and Sanford, Samuel. Useful Minerals of the United States (A Revision of Bulletin 585 (250 pp.) Washington, 1914).

U. S. Geol. Survey Bull. 624, 412 pp., Washington, 1917.

Lists following minerals and rocks from Lehigh County: allanite, calamine, cement material, clay, native copper, corundum, fluorspar, goslarite, granite, graphite, greenockite, malachite, manganese ore, mica, molybdenite, psilomelane, pyrite, pyro-

lusite, molding sand, sauconite, yellow shale, slate, smithsonite, sphalerite, wad, wavellite, whetstone.

Water Supply Commission of Pennsylvania. Water Resources Inventory Report.

Part III, Gazetteer of Streams, 657 pp., Harrisburg, 1917.

Gives natural and artificial features of Lehigh River and Trout, Spring, Little Lehigh, and Jordan creeks.

Part VIII, Floods, 108 pp., Harrisburg, 1917.

Describes floods of the Lehigh River.

Watson, Thomas L. Weathering of Allanite.

Geol. Soc. America Bull., vol. 28, pp. 463-500, New York, 1917.

Describes the occurrence of lanthanite "resulting from the decomposition of allanite" at Colesville (pp. 471-472).

Williams, Edward Higginson, Jr. Pennsylvania glaciation; first phase.

101 pp., map, 56 figures, Woodstock, Vermont, 1917.

Contains many descriptions of the glacial deposits of Lehigh County.

1918

Hintze, F. F. Age of the Martinsburg Shale as Interpreted from its Structural and Stratigraphical Relations in Eastern Pennsylvania (abstract).

Geol. Soc. America Bull., vol. 29, pp. 94-95, New York, 1918.

The author, having in mind some isolated occurrences of Martinsburg shale in Bucks and Lehigh counties, particularly the one at Limeport, suggests a probable unconformity within the Martinsburg with the upper part distinctly younger than the lower.

Shaw, Eugene Wesley. Ages of Peneplains of the Appalachian Province.

Geol. Soc. America Bull., vol. 29, pp. 579-586, New York, 1918.

Presents evidence to show that the oldest peneplanes now represented in the Appalachian region are no older than Tertiary and perhaps Middle Tertiary.

Wherry, Edgar T. Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania.

Geol. Soc. America Bull., vol. 29, pp. 375-392, New York, 1918. (Abstract in vol. 28, p. 156, 1917.)

Describes quartz-mica schists, graphite-bearing quartzite, and basic (amphibolite) gneiss of pre-Cambrian age in Lehigh County and argues for their sedimentary origin. Article illustrated by photomicrographs and other figures.

1920

Barrell, Joseph. The Piedmont Terraces of the Northern Appalachians.

Am. Jour. Sci., 4th ser., vol. 49, pp. 227-258, 327-362, 407-428, 6 plates, 18 figures, New Haven, 1920. Arranged and edited by H. H. Robinson from notes and unfinished manuscripts left by Prof. Barrell.

Describes peneplanes, wind gaps, and water gaps in eastern Pennsylvania, with specific references to Lehigh Gap.

Heller, William J. History of Northampton County and the Grand Valley of the Lehigh.

Two parts bound in 3 vols., General History 536 pp. and Biography 655 pp., American Historical Society, New York, 1920.

Describes the Friedensville zinc mines and works.

Water Supply Commission of Pennsylvania. Water Resources Inventory Report.

Part VI, Water Supply, 1,387 pp., 1920.

Describes water supplies of Allentown, Bethlehem, Northampton, North Catasauqua, Coopersburg, Emmaus, Emerald, Slatedale, Macungie, Slatington, Fountain Hill and Salisbury Township (part).

Williams, Edward H., Jr. The Deep Kansan Pondings in Pennsylvania and the Deposits Therein.

Am. Philos. Soc. Proc., vol. 19, pp. 49-84, Philadelphia, 1920.

Brief mention of glacial phenomena in the Lehigh Valley.

1921

Bascom, F. Cycles of Erosion in the Piedmont Province of Pennsylvania.

Jour. Geol., vol. 29, pp. 540-559, Chicago, 1921.

Describes five peneplanes in Pennsylvania all of which should be represented in Lehigh County although only a few localities within the county are specifically mentioned. Peneplanes described are Kittatinny (1800′-1100′), Schooley (1300′-900′), Honeybrook (860′-700′), Harrisburg (800′-500′), and Early Brandywine (500′-390′).

Peters, Richard, Jr. Two Centuries of Iron Smelting in Pennsylvania.

83 pp., illustrated, Philadelphia, 1921.

Contains considerable information concerning the early iron industry in the Lehigh Valley.

1922

Berlin, Alfred F. The Bake Oven Knob.

Lehigh County Hist. Soc. Proc. (for 1922), pp. 44-48, Allentown, 1922.

Describes the geology of the Bake Oven. Most of the information was obtained from the writings of Prof. E. H. Williams, Jr.

Bowles, Oliver. The Technology of Slate.

U. S. Bur. Mines Bull. 218, 132 pp., 6 pls., 41 figs., Washington, 1922.

Deals with the technology of the slate industry but contains numerous descriptions of geologic features observed in quarries in Lehigh County.

Gordon, Samuel G. The Mineralogy of Pennsylvania.

Acad. Nat. Sci. Philadelphia Sp. Pub. No. 1, 255 pp., Philadelphia, 1922.

Describes all the minerals known to occur in the State and gives list of minerals and specific localities for each county with literature references. Cites many minerals from Lehigh County.

Kelsey, Rayner Wickersham. Casenove Journal, 1794. A record of the journey of Theophile Cazenove through New Jersey and Pennsylvania.

Translated from the French manuscript in Library of Congress, 103 pp., 5 plates, Haverford, 1922.

Traveled from Bethlehem to Reading, stopping at Allentown and Trexlertown, etc. Brief descriptions of physical features. Refers to Big Spring, ½ mile west of Trexler's Tavern.

Wherry, Edgar T. and Shannon, Earl V. Crocidolite from Eastern Pennsylvania.

Washington Acad. Sci. Jour., vol. 12, pp. 242-244, Washington, 1922.

A blue mineral, previously called glaucophane, occurring near Limeport and in other localities, is determined to be crocidolite.

Wyer, Samuel S. The Smithsonian Institution's Study of Natural Resources Applied to Pennsylvania's Resources.

150 pp., Washington, 1922.

Interesting generalizations concerning Pennsylvania's resources. Discussions of limestones, lime, and cement apply to Lehigh County.

1923

Berlin, Alfred Franklin. The Arrowhead.

Lehigh County Historical Society for 1923, pp. 47-63, Allentown, 1923.

Describes the jasper occurrences of Vera Cruz and Macungie, and others in Berks and Bucks Counties.

1924

Behre, Chas. H., Jr. Observations on structures in the slates of Northampton County, Pennsylvania.

Jour. of Geol., vol. 34, pp. 481-506, 1926.

Structures described are applicable to the interpretation of the Martinsburg strata of Lehigh County.

Brown, Thomas Clacher. Origin of Oolites and the Oolitic Texture in Rocks.

Geol. Soc. America Bull., vol. 35, pp. 745-780, plates 26-28, New York, 1924.

Refers briefly to calcareous and siliceous oolites in the vicinity of Allentown and Bethlehem.

EVANS, W. F. Friedensville Zinc Mines.

Lehigh County Hist. Soc., Ann. Proc., 1924, pp. 63-66, Allentown, 1924.

Concise description of the history of the operations of the Friedensville zinc mines.

FOX, R. L. and GROSSHART, L. J. H. Water Supply of the Lehigh Valley.

Engineers Club of the Lehigh Valley Proc., Spring issue, 6 pp., 1924.

A discussion of the water situation in the Lehigh Valley with a brief statement concerning the source of supply of each municipality.

KNOPF, ELEANORA B. Correlation of residual erosion surfaces in the eastern Appalachian Highlands.

Geol. Soc. Am. Bull., vol. 35, pp. 633-668, 1924.

Identifies and correlates remnants of 10 erosion surfaces in Pennsylvania of which 7 are represented in Lehigh County. They are in order of decreasing elevation and decreasing age—Kittatinny (1660′), Schooley (1400′-1300′), Mine Ridge (1100′-1000′), Honeybrook (900′-840′), Sunbury (700′-600′), Harrisburg (Bryn Mawr?) (560′-500′), Lancaster (Brandywine?, Somerville) (440′-400′). Presents maps of different periods showing development of present drainage.

LESLEY, ROBERT W. History of the Portland Cement Industry in the United States.

330 pp., plates and figures, Chicago, 1924.

An excellent account of the history of the portland cement industry in the Lehigh District of Lehigh and Northampton Counties.

MILLER, BENJAMIN LEROY. Lead and Zinc Ores of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 5, 89 pp., Harrisburg, 1924.

Describes the Friedensville zinc region of Lehigh County.

MOORE, E. S., and TAYLOR, T. G. The Silica Refractories of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 3, 99 pp., Harrisburg, 1924.

Brief mention is made of the siliceous sediments of Blue Mountain.

1925

ASHLEY, GEORGE H. Silurian Stratigraphy at Lehigh Gap, Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. 88, 6 pp., Harrisburg, 1925.

Gives measurements at Lehigh Gap of 250 feet of Tuscarora sandstone, 555 feet of Juniata sandstone and shale, and 464 feet of Oswego sandstone.

BEHRE, CHARLES H., Jr. Taconic Folding in the Martinsburg Shales (abst.).

Geol. Soc. America Bull., vol. 36, pp. 157-158, New York, 1925.

Evidence presented to show that the Taconic disturbance was in eastern Pennsylvania "almost if not quite as violent as the Appalachian revolution."

ESPENSHADE, A. HOWRY. Pennsylvania Place Names.

375 pp., State College, 1925.

Contains considerable geographic information concerning Lehigh County.

MILLER, BENJAMIN LEROY. Limestones of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 7, 368 pp., 15 plates, 7 figures, Harrisburg, 1925.

Contains much data concerning the limestones of Lehigh County and their adaptabilities.

MILLER, BENJAMIN LEROY. Mineral Resources of the Allentown Quadrangle.

Pennsylvania Topog. and Geol. Survey Atlas 206, 195 pp., map, illustrations, Harrisburg, 1925.

A description of the mineral resources of that portion of Lehigh County embraced within the Allentown quadrangle.

MILLER, BENJAMIN LEROY. Taconic Folding in Pennsylvania (abstract).

Geol. Soc. America Bull., vol. 36, p. 157, New York, 1925.

Attention called to a marked unconformity at the base of the Shawangunk.

1926

Behre, Chas. H., Jr. Structures in the Slates of Northeastern Pennsylvania (abstract).

Geol. Soc. Am. Bull., vol. 35, pp. 100-101, 1924.

Brief descriptions of the different members of the Martinsburg formation and prevailing structures.

Meade, Richard K. Portland Cement: Its composition, raw materials, manufacture, testing and analysis.

3d ed., 707 pp., Easton, 1926. Previous editions published in 1906 and 1911.

Contains descriptions of the raw materials and the processes of manufacture of portland cement in the Lehigh District.

Miller, B. L. Taconic Folding in Pennsylvania.

Geol. Soc. of America Bull., vol. 37, pp. 497-512, New York, 1926.

Evidence presented to prove period of orogenic activity at close of Martinsburg deposition and pronounced unconformity between Martinsburg and Shawangunk formations.

1927

Behre, Charles H., Jr. Slate in Northampton County, Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 9, 308 pp., Harrisburg, 1927.

An exhaustive account of the stratigraphy, structure, and economic features of the slate region of Northampton County. Most of the features described apply equally to the slate district of Lehigh County.

Stose, George W., and Jonas, Anna I. Ordovician shale and associated lava in southeastern Pennsylvania.

Geol. Soc. Am. Bull., vol. 38, pp. 505-536, 1927.

Discusses relations of the Martinsburg, Leesport, and Allentown formations in the Egypt and Limeport regions.

Stose, George W. Possible Post-Cretaceous Faulting in the Appalachians.

Geol. Soc. Am. Bull., vol. 38, pp. 493-504, 1927.

Suggests the correlation of the Kittatinny and Schooley peneplanes. The greater elevation of the peneplane on Kittatinny Mountain as compared with the one developed on Scott and Schooley Mountains (N. J.) is explained by normal faulting in post-Cretaceous and pre-Harrisburg peneplanation time.

1928

Behre, Charles H., Jr. Geologic Factors in the Development of the Eastern Pennsylvania Slate Belt.

Amer. Inst. Min. and Met. Eng. Trans., vol. 76, pp. 393-412, New York, 1928.

Describes particularly the structural features of the Martinsburg slates of the Lehigh slate district.

Donehoo, George P. A History of the Indian Villages and Place Names in Pennsylvania.

290 pp., Harrisburg, 1928.

Important geographic information concerning Lehigh County. The following topics are discussed: Delaware Indians, Hockendauqua, Lehigh, Macungie, Monocacy, Saucon, etc.

Eckel, Edwin C. Cements, Limes and Plasters.

3d ed., 699 pp., 161 figures, New York, 1928. Previous editions published in 1905 and 1922.

Contains many descriptions of the cement industry of the Lehigh Valley.

Fenneman, Nevin M. Physiographic Divisions of the United States, 3d ed.

Annals of the Assoc. of Am. Geographers, vol. 18, pp. 261-353, 1928.

Map shows the different physiographic divisions represented in eastern Pennsylvania, with brief descriptions in the text.

STONE, R. W. Molding Sands of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 11, 94 pp., 21 pl., 10 figs., Harrisburg, 1928.

Discusses tests for molding sand, origin and geology and descriptions of samples tested, including materials from three localities in Lehigh County.

WILLARD, BRADFORD. The Age and Origin of the Shawangunk Formation.

Jour. Paleont., vol. 1, no. 4, pp. 255-258, 1928.

Contains description of stratigraphy in Delaware and Lehigh water gaps.

1929

ERBE, HELLMUTH. Bethlehem, Pa. Eine kommunistische Herrnhuter Kolonie des 18. Jahrhunderts.

191 pp., 8 plates, Stuttgart, 1929, Lehigh Univ. Library.

Contains considerable geographic information and copies of early maps. Excellent bibliography.

KNOPF, ELEANORA BLISS, and JONAS, ANNA I. Geology of the McCalls Ferry-Quarryville District, Pennsylvania.

U. S. Geol. Survey Bull. 799, 156 pp., Washington, 1929.

Discusses the peneplanes and physiographic development of southeastern Pennsylvania, including Lehigh County. Presents generalized maps.

WILLARD, BRADFORD. Stratigraphic Aspect of Taconic Disturbance.

Pan-American Geologist, vol. 51, pp. 93-96, Des Moines, 1929.

A summary of events during late Ordovician and early Silurian as interpreted from the geologic sections at Delaware Water Gap and Lehigh Gap.

1930

KNAUSS, O. P. Jasper Quarries at Macungie.

Lehigh County Hist. Soc. Ann. Proc., pp. 13-15, Allentown, 1930.

Short account of the old Indian jasper workings at Macungie and Vera Cruz.

PIRSSON, LOUIS V., and LONGWELL, CHESTER R. Outlines of Physical Geology.

376 pp., New York, 1930.

Formation of water gaps described, with cut of Lehigh Water Gap as an example. Gives cut showing slaty cleavage in slate quarry at Slatington.

SHAW, JOSEPH B. The Ceramic Industries of Pennsylvania.

School of Min. Ind., Pennsylvania State College, Bull. 7, 206 pp., State College, 1930.

A general account of the ceramic industries of the State, with a list of producers. Contains some facts regarding the clay, brick, and cement plants of Lehigh County.

STOSE, GEORGE W. Unconformity at the Base of the Silurian in Southeastern Pennsylvania.

Geol. Soc. America Bull., vol. 41, pp. 629-658, abstract, p. 88, New York, 1930.

States that the Martinsburg shale is made up of two members and the Medina unconformably overlies the lower member.

VER STEEG, KARL. Windgaps and Watergaps of the Northern Appalachians, Their Characteristics and Significance.

Annals of New York Acad. Sci., vol. 32, pp. 87-220, 172 figures, New York, 1930.

An elaborate discussion of the gaps in Blue Mountain and other similar ridges. The paper is discussed by W. O. Hickok in Am. Jour. Sci., 5th ser., vol. 25, pp. 101-122, 1933, and a reply by Ver Steeg is contained in same periodical, 5th ser., vol. 26, pp. 507-511, 1933. Is again discussed in same journal, vol. 27, pp. 410-416, 1934, by Howard A. Meyerhoff and Elizabeth W. Olmsted. Ver Steeg continues discussion in vol. 30, pp. 98-105, 1935 and reply is given by Meyerhoff and Olmsted in vol. 31, pp. 391-393, 1936.

WARD, FREEMAN. The Role of Solution in Peneplanation.

Jour. Geology, vol. 38, pp. 262-270, Chicago, 1930.

Attributes the development of the so-called "Somerville peneplane" to the work of solution rather than ordinary surface erosion.

Woolf, D. O. The Results of Physical Tests of Road-Building Rock.
U. S. Dept. Agr. Misc. Pub. 76, 148 pp., Washington, 1930.

Gives physical tests of seven samples of dolomite, "diorite," gneiss, and syenite from Lehigh County (p. 97).

1931

Ashley, George H. A Syllabus of Pennsylvania Geology and Mineral Resources.
Pennsylvania Topog. and Geol. Survey Bull. G 1, 160 pp., 2 plates, 118 figures, Harrisburg, 1931.

Contains many brief descriptions of the geology and mineral products of Lehigh County.

Blank, Eugene W. The Old Friedensville Zinc Mine.
Rocks and Minerals, vol. 6, no. 1, pp. 26-27; Peekskill, N. Y., 1931.

Stose, George W., and Ljungstedt, O. A. Geologic Map of Pennsylvania.
Pennsylvania Topog. and Geol. Survey, scale: 1 inch = 6 miles, Harrisburg, 1931.

Shows generalized geologic formation lines of Lehigh County.

Swartz, Charles K., and Swartz, Frank M. Early Silurian Formations of Southeastern Pennsylvania.
Geol. Soc. America Bull., vol. 42, pp. 621-662, New York, 1931.

Gives a detailed geologic section through Lehigh Gap (pp. 641-644).

Ver Steeg, Karl. Warping of Appalachian Peneplanes.
Jour. Geol., vol. 39, pp. 386-392, Chicago, 1931.

Concludes that "the uplift of the Harrisburg surface appears to have been, in eastern Pennsylvania, a vertical one unaccompanied by widespread warping."

1932

Brown, Col. Earl I. Report on Lehigh River, Pa., Covering Navigation, Flood Control, Power Development, and Irrigation.
49 pp., 18 maps and profiles, U. S. War Dept., Washington, 1932.

Contains a mass of useful information concerning the Lehigh River.

Burkhardt, F. A. Tracks, Trails and Traces of Lehigh Valley Regions.
Lehigh County Hist. Soc. Ann. Proc., Allentown, 1932, pp. 3-17.

Says an Indian village was located where Central Park now is.

Deisher, Henry K. Quarrying.
Bucks County Hist. Soc., vol. 6, pp. 33-41, Allentown, 1932.

Brief descriptions of the jasper quarries at Vera Cruz and Macungie (pp. 33-34) and the slate quarries near Slatington (pp. 37-38).

Deisher, Henry K. South Mountain Indian Quarries.
Bucks County Hist. Soc., vol. 6, pp. 334-341, Allentown, 1932.

Further descriptions of the Indian jasper quarries at Vera Cruz and Macungie (pp. 337-339).

Fackenthal, B. F., Jr. Improving Navigation On the Delaware River With Some Account of Its Ferries, Bridges, Canals and Floods.
Bucks County Hist. Soc., vol. 6, pp. 103-230, Allentown, 1932.

Descriptions of the Delaware and Lehigh Rivers and the Lehigh Canal.

Johnson, Douglas, Bascom, Florence, and Sharp, Henry S. Geomorphology of the Central Appalachians.
XVI International Geological Congress, Guidebook 7, 50 pp., 2 plates, 28 figures, Washington, 1932.

Describes the physiographic divisions represented in Lehigh County.

Kessler, D. W., and Sligh, W. H. Physical Properties and Weathering Characteristics of Slate.
U. S. Bur. Standards Jour. of Research, vol. 9, pp. 377-411, 8 figures, Washington, 1932. Reprinted as Bur. Standards Research Paper 477.

Various physical properties of several specimens of slate from different slate companies in Lehigh County were determined and general conclusions stated.

LONGWELL, CHESTER R., KNOPH, ADOLPH, and FLINT, RICHARD F. A Textbook of Geology, Part I, Physical Geology.

514 pp., New York, 1932.

Cut and brief description of the Lehigh Water Gap. Profile of the Lehigh River.

McLAUGHLIN, DEAN B. The Thickness of the Newark Series in Pennsylvania and the Age of the Border Conglomerate.

Michigan Acad. Sci., Arts and Letters, vol. 16, pp. 421-427, 1931. Published 1932.

Believes that the Triassic conglomerate along the southeast border of Lehigh County is of Brunswick age.

MILLER, BENJAMIN L. The Lehigh Portland Cement District, Pennsylvania.

XVI International Geological Congress, Guidebook 8, pp. 30-40, 2 plates, Washington, 1932.

A concise description of the geology, history, and processes of manufacture.

SCOTT, WILLIAM BERRYMAN. An Introduction to Geology, Vol. I, Physical Geology.

3d ed., 604 pp., New York, 1932.

Lehigh Water Gap mentioned and cut of slate strata exposed.

STONE, RALPH W. Building Stones of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 15, 316 pp., 4 plates, 164 figures, Harrisburg, 1932.

Describes different kinds of stone, uses, character, geology, and some important quarries of building stone in Lehigh County (pp. 196-199).

VER STEEG, KARL. Map of the Schooley (Kittatinny) Peneplane.

Jour. Geology, vol. 40, pp. 557-559, Chicago, 1932.

Shows peneplane in eastern Pennsylvania by means of contours. Identifies Kittatinny and Schooley peneplanes as the same.

1933

ASHLEY, GEORGE H. The Scenery of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. G 6, 91 pp., 90 figures, Harrisburg, 1933.

Contains descriptions of the peneplanes developed in Lehigh County. Summarizes the work of F. Leverett and F. Ward on the glacial ice sheets of the region.

BEHRE, CHARLES H., Jr. Slate in Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 16, 400 pp., 70 plates, 89 figures, Harrisburg, 1933.

An extensive report on slate, with many descriptions of the deposits of Lehigh County.

DEISHER, HENRY K. South Mountain Indian Quarries.

Pennsylvania Archaeologist, vol. 3, pp. 6-7, 18-19, Harrisburg, 1933.

Brief description of the Lehigh County locations where the Indians quarried jasper near Limeport, Vera Cruz, and Macungie.

HICKOK, W. O., 4TH. Erosion Surfaces in South-Central Pennsylvania.

Am. Jour. Sci., 5th ser., vol. 25, pp. 101-122, 1933. See Ver Steeg, 1930.

Concludes that the wind gaps of the Appalachians in Pennsylvania "fall into narrow horizontal zones which may indicate the presence of several erosion surfaces between 900 feet and 1,650 feet elevation."

VER STEEG, KARL. Windgaps and Erosion Surfaces.

Am. Jour. Sci., 5th ser., vol. 26, pp. 507-511, 1933. See Ver Steeg, 1930.

Disagrees with Hickok. Concludes that in the Appalachian region "there is no accordance in wind gap elevations and that they do not mark fluvial base levels."

1934

COLLINS, W. D., LAMAR, L. W., and LOHR, E. W. The Industrial Utility of Public Water Supplies in the United States, 1932.

U. S. Geol. Survey Water Supply Paper 658, pp. 108-109, Washington, 1934.

Brief description and analyses of the water supply of Allentown and Bethlehem.

Fretz, A. Henry. The Burden of Lehigh River in One Year.

Pennsylvania Acad. Sci. Proc., vol. 8, pp. 92-94, Harrisburg, 1934.

Gives statistics of the amount of soluble and insoluble material carried past Bethlehem during a year of observation.

Fuller, J. Osborn. Preliminary Staining Studies of the Lehigh Valley Dolomitic Limestones.

Pennsylvania Acad. Sci. Proc., vol. 8, pp. 83-87, 1 fig., Harrisburg, 1934.

Describes results obtained in staining specimens of the Cambrian and Ordovician limestones of the Lehigh Valley.

Hall, George M. Ground Water in Southeastern Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. W 2, 255 pp., 7 plates, 7 figures, Harrisburg, 1934.

Describes the underground water conditions in Lehigh County.

Leverett, Frank. Glacial Deposits Outside the Wisconsin Terminal Moraine in Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. G 7, 123 pp., 2 plates, 38 figures, Harrisburg, 1934.

Discusses particularly the Illinoian ice sheet in the vicinity of Emmaus.

Meyerhoff, Howard A., and Olmsted, Elizabeth W. Wind gaps and Water gaps in Pennsylvania.

Am. Jour. Sci., 5th ser., vol. 27, pp. 410-416, 1934. See Ver Steeg, 1930.

"The Appalachian region of Pennsylvania contains the record of several erosional levels of fluvial origin. The positions of these levels are indicated with moderate accuracy by *groups* of water gaps and wind gaps."

Miller, Benjamin LeRoy. Limestones of Pennsylvania.

Pennsylvania Topog. and Geol. Survey Bull. M 20, 729 pp., 41 plates, 34 figures, Harrisburg, 1934.

Contains descriptions of the limestone resources of Lehigh County.

Myers, Philip B. The Origin of Jaspers in Lehigh and Northampton Counties, Pennsylvania.

Pennsylvania Acad. Sci. Proc., vol. 8, pp. 87-92, 1 fig., Harrisburg, 1934.

The microscopic characteristics of the jasper of the Hardyston formation are described and their origin discussed.

Torrey, Raymond H., and others. Guide to the Appalachian Trail, from the Housatonic River to the Susquehanna River.

88 pp., New York, 1934.

Describes the trail on the crest of Blue Mountain from the Lehigh River to the Berks County line (pp. 58-61) with route map.

Warmkessel, Carl A. Burden of Lehigh River During the Flood of August, 1933.

Pennsylvania Acad. Sci. Proc., vol. 8, pp. 94-96, Harrisburg, 1934.

Gives figures of kind and amount of material carried past Allentown and Bethlehem during the 1933 flood.

1935

Ashley, George H. Studies in Appalachian Mountain Sculpture.

Geol. Soc. America Bull., vol. 46, pp. 1395-1436, 8 plates, 14 figures, New York, 1935.

Discusses the peneplane problem and specifically refers to Lehigh County localities. Concludes that there has been only one period of peneplanation.

Butler, Robert D. Mylonitic Sphalerite from Friedensville, Pennsylvania.

Econ. Geology, vol. 30, pp. 890-904, 1935.

From the study of polished sections of the homogeneous massive sphalerite from Friedensville, the author concludes that "plastic deformation and granulation subsequent to the emplacement of the ore produced the fine-grained or mylonitic facies."

Faux, F. R. Aragonite at Allentown, Pennsylvania.

Rocks and Minerals, vol. 10, p. 174, 1935.

A short description of a cave containing fine aragonite specimens. Cave was in the Ziegenfuss quarry in southwest part of Allentown.

Fraser, Donald M. Microscopic Investigation of Friedensville, Pennsylvania, Zinc Ore.

Am. Mineralogist, vol. 20, pp. 451-461, 1935.

Concludes that "silica solutions, later richer in sulphides, invaded the limestone. Quartz first intimately replaced the limestone and was deposited in veinlets; later, sphalerite replaced the carbonate and in places quartz."

Fraser, Donald M. Igneous Assimilation near Macungie, Pennsylvania.

Pennsylvania Acad. Sci. Proc., vol. 9, pp. 34-38, 2 figs., 1935.

Petrographic studies of some of the pre-Cambrian metamorphic rocks near Macungie have furnished evidence of mineralogic changes due to successive igneous intrusions.

Garrison, Hazel Shields. Cartography of Pennsylvania before 1800.

Pennsylvania Mag. of Hist. and Biog., vol. 59, pp. 255-283, 1935.

Among others the work of Lewis Evans, Nicholas Scull, William Scull, and Reading Howell is described. All of these include the area now comprising Lehigh County.

Hills, John M. The Insoluble Residues of the Cambro-Ordovician Limestones of the Lehigh Valley, Pennsylvania.

Jour. Sedimentary Petrology, vol. 5, pp. 123-132, 3 figures, 1935.

The limestones exposed along the Delaware and Lehigh Rivers were studied in considerable detail. Concludes that "while the method of insoluble residues can not be recommended for independent use in regions of complex structure, it is very valuable as an adjunct to conventional field methods in determining stratigraphic succession and establishing more exact lithological correlations."

Myers, Richmond E. The Story of the Zinc Industry in the Saucon Valley.

Rocks and Minerals, vol. 10, pp. 17-21, 33-36, 56-59, Peekskill, 1935.

An excellent historical account.

Stose, George W., and Jonas, Anna I. Highlands near Reading Pennsylvania; an Erosion Remnant of a Great Overthrust Sheet.

Geol. Soc. America Bull., vol. 46, pp. 757-779, maps and figures, 1935.

Advances the theory that the crystalline rocks of the Reading region and extending northeastward into Lehigh County constitute a part of a great overthrust block.

Ver Steeg, Karl. Wind gaps and Water gaps; Their Value as Indicators of Erosion Surfaces.

Am. Jour. Sci., 5th ser., vol. 30, pp. 98-105, New Haven, 1935.

Reviews the work of Bascom (1921), Barrell (1920), Knopf (1924), Stose (1928), Meyerhoff and Olmsted (1934). States that "since the water gaps of today have varying elevation and are known not to represent a peneplane of fluvial base level, the still more irregular wind gaps cannot be regarded as reliable evidence of former base levels." See Ver Steeg, 1930.

1936

Billinger, R. D. Early Zinc Works in the Lehigh Valley.

Jour. Chem. Education, vol. 13, pp. 60-62, 1936.

A brief historical account of the operations of the companies concerned with the Friedensville zinc deposits.

Fraser, Donald M. Sericitization in the Pennsylvania Highlands.

Pennsylvania Acad. Sci. Proc., vol. 10, pp. 66-71, 4 figs., 1936.

Describes the formation of sericite in schist and gneiss in the pre-Cambrian metamorphic rocks of the Reading Hills.

Itter, Harry Augustus. The Geomorphology of the Wyoming-Lackawanna Region.

87 pp., Easton, 1936. (Privately printed.)

Pennsylvania Topog. and Geologic Survey Bull. G 9, 82 pp., 9 plates, 46 figures, 1938.

Discusses ancient drainage systems of eastern Pennsylvania and New Jersey, including Lehigh County.

Meyerhoff, H. A., and Olmsted, E. W. Wind- and Water-gap Systems in Pennsylvania.

Am. Jour. Sci., vol. 31, 5th ser., pp. 391-398, New Haven, 1936.

Further discussion of relation between wind gap elevations and fluvial erosion surfaces. See Ver Steeg, 1930.

Meyerhoff, H. A., and Olmsted, E. W. The Origins of Appalachian Drainage.

Am. Jour. Sci., 5th ser., vol. 32, pp. 21-42, 1936.

A discussion of the major streams of the Appalachian area, including Delaware River. The Triassic conglomerates of Flint Hill are believed to have been formed by the Triassic Lehigh River.

Miller, B. L. and Fraser, D. M., Stose, G. W., and Jonas, A. I. Comment by Miller and Fraser on paper published by Stose and Jonas: Highlands near Reading; an erosion remnant of a great overthrust block, (Bull. Geol. Soc. of Amer., vol. 46, pp. 757-779, 1935) with reply by Stose and Jonas.

Geol. Soc. America Bull., vol. 46, pp. 2031-2040, 1936.

Specific facts are presented to disprove the overthrust theory.

Roberts, Charles R. Place Names of Lehigh County and Their Origin.

Lehigh County Hist. Soc. Ann. Proc., pp. 5-12, Allentown, 1936.

Gives origin of many of the Lehigh County geographic names.

Ryder, C. E. The Floods of March 1936 in Pennsylvania.

Department of Forests and Waters, Commonwealth of Pennsylvania, 129 pp., Harrisburg, 1936.

Describes the floods of the Lehigh River during March, 1936.

1937

Fraser, Donald M. Replacement of Hardyston Quartzite by Jasper.

Pennsylvania Acad. Sci. Proc., vol. 11, pp. 57-61, 3 figs., Harrisburg, 1937.

Presents petrographic evidence to show that jasper found in Lehigh and Northampton counties has been formed by the replacement of quartz grains.

Miller, Ralph L. Martinsburg limestones in eastern Pennsylvania.

Geol. Soc. Am. Bull., vol. 48, pp. 2032-2037, 1937.

Descriptions are pertinent to geologic problems in Lehigh County.

Miller, Ralph L. Stratigraphy of the Jacksonburg Limestone.

Geol. Soc. America Bull., vol. 48, pp. 1687-1718, ill., New York, 1937.

Discusses paleontologic, stratigraphic, and structural characteristics of the Jacksonburg.

Sherman, L. D. Lehigh River Flood Control Survey.

Works Progress Administration Project 8675, U. S. Engineer Office, War Department, Philadelphia, 1937.

A series of forty-seven blueprint topographic charts of the flood plains of the Lehigh River and lower portions of tributaries from Easton to Laurys. Also profiles of Lehigh and Delaware Rivers and tributaries. Charts on scales of 1 inch = 100 or 200 feet and 1 to 5,000.

1938

Mackin, J. Hoover. The Origin of Appalachian Drainage—A Reply.

Am. Jour. Sci., 5th ser., vol. 36, pp. 27-53, 1938.

Discusses paper by Meyerhoff and Olmsted published in 1936. Disagrees with the authors and accepts theory of D. Johnson.

Miller, Benjamin L. Breathing Caverns of the Lehigh Valley.

Pennsylvania Acad. Sci. Proc., vol. 12, pp. 105-107, Harrisburg, 1938.

Describes in-going and out-going air currents in limestone cavities in East Allentown and along Club Avenue.

1939

FRASER, DONALD M., and GETZ, ALBERT J. Notes on Hardyston Quartzite.

Pennsylvania Acad. Sci. Proc., vol. 13, pp. 94-97, 1 fig., Myerstown, 1939.

Contains petrographic descriptions of some specimens of Hardyston quartzites from the Reading and Durham Hills. Conclude that hydrothermal waters have been active agents.

GIPSON, LAWRENCE HENRY. Lewis Evans.

219 pp., maps, Philadelphia, 1939.

Contains facsimiles of Evans' maps and writings, described in this bibliography under the years 1749, 1750, 1753, and 1755.

MILLER, BENJAMIN L., FRASER, DONALD M., and MILLER, RALPH L. Northampton County, Pennsylvania.

Pennsylvania Topog. and Geol. Survey, Bull. C 48, 496 pp., 29 plates, 36 figs., geologic map, Harrisburg, 1939.

Contains descriptions of the geography and geology of Northampton County. Many of the features described are present in Lehigh County.

MILLER, BENJAMIN L. Scolithus Tubes in Hardyston Sandstone.

Pennsylvania Acad. Sci. Proc., vol. 13, pp. 101-104, 1 fig., Myerstown, 1939.

Describes three types of *Scolithus* tubes found in the Hardyston sandstones of Lehigh and Northampton counties.

MILLER, BENJAMIN L. Guidebook to Places of Geologic Interest in the Lehigh Valley, Pennsylvania.

Pennsylvania Topog. and Geol. Survey, Bull. G 16, 47 pp., 24 figs., Harrisburg, 1939.

Contains short descriptions of the geologic features of the Lehigh Valley. Details are given of two itineraries mainly within the limits of Lehigh County; viz., Allentown to Center Valley and Allentown to Treichlers.

MILLER, BENJAMIN L. Rock ("Desert") Varnish in Eastern Pennsylvania.

Pennsylvania Acad. Sci. Proc., vol. 13, pp. 98-101, 1 fig., Myerstown, 1939.

Proposes that the limonite coating prominently developed on surface rocks in the Lehigh Valley should be designated "rock varnish" instead of "desert varnish" in view of the fact that the region has an annual rainfall of 42.64 inches.

WILLARD, BRADFORD. Ordovician Shales of Southeastern Pennsylvania.

Pennsylvania Acad. Sci. Proc., vol. 13, pp. 126-133, 1 fig., Myerstown, 1939.

Presents evidence in support of the belief that the Martinsburg should be regarded as a Group rather than a Formation. Some of the data were obtained from Lehigh County localities.

WILLARD, BRADFORD, and CLEAVES, ARTHUR B. Ordovician-Silurian relations in Pennsylvania.

Geol. Soc. Am. Bull., vol. 50, pp. 1165-1198, 1939.

A discussion of the stratigraphy of the Upper Ordovician.

1940

FRASER, DONALD M. Silicification and Local Granitization in the Reading Hills (Abstract).

Amer. Geophys. Union Trans. of 1940, pp. 359-362, 8 figs., Washington, 1940.

"Quartz and microcline replacing minerals in pre-Cambrian and Cambrian formations in the Reading Hills indicate a magmatic source for solutions that have introduced large volumes of material. This introduction was likely in post-Hardyston time."

MACCLINTOCK, PAUL. Weathering of the Jerseyan Till.

Geol. Soc. America Bull., vol. 51, pp. 106, 1940.

Refers to glacial deposits near Emmaus. Approves of Leverett's correlation of the pre-Wisconsin glacial deposits, such as occur in Lehigh County, to the Illinoian and Kansan ice sheets.

MYERS, RICHMOND E. The Hardyston Jasper of the Reading Hills in Pennsylvania.

Rocks and Minerals, vol. 15, pp. 219-225, Peekskill, 1940.

A discussion of the character and origin of jasper with descriptions on several localities where it can be found.

TOPONYMY

BY BENJAMIN L. MILLER

There is general interest in the derivation of place names, mainly because of the historic significance, but also on account of an innate curiosity that is almost universal. In many instances the reasons for the designation are obvious, as, for example, the naming of a town "Mountainville" when it is located at the foot or on the top of a mountain; calling a stream "Rock Creek" when its channel or valley is conspicuously rocky; or naming a stream with numerous meanders "Crooked Creek." In other cases the reasons are not apparent and are not known even to the inhabitants of the region. It is also not unusual to find conflicting explanations. When this occurs, the different origins are given. It is probable that some of the interpretations offered here will be challenged. It is hoped that any disagreements of this sort will be made available to the writer and others interested in this subject.

In such an area as Lehigh County, with a recorded history of less than 240 years, it is usually, but not always, possible to discover why the place names have been assigned. In other parts of the world, toponymic investigators encounter almost insuperable difficulties.

The data for this chapter have been collected during an investigation of the maps and descriptive materials dealing with this area; individuals familiar with some phases of the study have also contributed. Both published and manuscript documents have been consulted, local histories, travel books, newspapers, etc. The more important of these are included in the Bibliography and Cartography which constitute another chapter in this volume and, in general, do not require specific mention here. A few are listed because of their especial value in compiling the data. They are as follows:

HECKEWELDER, JOHN. Names which the Lenni Lenape or Delaware Indians gave to Rivers, Streams and Localities within the States of Pennsylvania, New Jersey, Maryland and Virginia with their significance. Moravian Hist. Soc. Trans., vol. 1, pp. 225-282, Nazareth, 1872.

ROBERTS, CHARLES RHOADS, STOUDT, JOHN BAER, KRICK, THOMAS H., and DIETRICH, WILLIAM J. History of Lehigh County, Pennsylvania and a genealogical and biographical record of its families. Two vols. (bound in three parts), pp. 1101 and 1467, Allentown, 1914.

ESPENSHADE, A. HOWRY. Pennsylvania Place Names, 375 pp., State College, 1925.

DONEHOO, GEORGE P. A History of the Indian Villages and Place Names in Pennsylvania, 290 pp., Harrisburg, 1928.

ROBERTS, CHARLES R. Place Names of Lehigh County and Their Origin. Lehigh County Hist. Soc. Ann. Proc., pp. 5-12, Allentown, 1936.

The names given to the natural features of Lehigh County and to the settlements and political divisions reveal several different tendencies. An attempt is made to classify the place names, although admittedly such a classification must be artificial and must involve arbitrary assignments with little justification in some cases.

An effort has been made to include all place names that have ever been in common use even though now obsolete. It is realized, however, that probably there are other local names not known to the writer and which have not been used on maps or in published articles. Someone might well endeavor to collect these. The names of churches and schools have not been included, although these possess historic value and in some cases have been applied to small settlements.

1. *Indian names.*—Although only a relatively few Indian place names remain in use, they nevertheless deserve priority. The Indians attached names to some of the most important streams and mountains and to some of their rather temporary settlements. These seem to have been chosen almost universally because of some characteristic feature. Generally they were compound words or even in some cases almost complete sentences. The early settlers endeavored to retain the Indian names, but with indifferent success. Some of the names were long and were perhaps spoken by the Indians indistinctly or with variations by different individuals. Therefore, it is not surprising that there should be different spellings when these were reduced to writing. The best illustration of this in this region is the name "Monocacy." The writer has found in the records and maps 37 spellings other than the one now in use (as shown on a later page), but in every case the pronunciation is almost if not quite the same. Each of the four syllables has from three to nine different spellings, so that still other combinations may be found.

These names have undergone such changes that in some cases the terms now in use bear little resemblance to the original Indian designations. In general the names were shortened, but some have been corrupted in ways not satisfactorily explained. For example, the change from "Lechauweki" to "Lehigh" involved numerous modifications, some of which do not appear logical, as described on a later page.

The following Indian names have been preserved, with all except the last one in current use:

Indian Place Names

Catasauqua
Coplay
Hokendauqua
Kittatinny
Lehigh
Macungie
Monocacy
Ontelaunee
Perkiomen
Saucon
Tuppeckhanna

2. *Family names of early residents.*—The names of families or some particular individuals constitute the greatest number of place names of Lehigh County. The taverns of an early day were almost always known by the names of the proprietors, and as these localities developed into settlements, the names were extended to include the entire community. When the tavern changed owners, the name of the settlement also changed in many cases, so that difficulty is experienced in identifying some of these old place names now in disuse. Creeks and hills likewise have at times borne different names because

of the arrival of new families in the particular regions. Creeks were commonly named for a family that operated a mill on the stream, and changed names when the ownership of the mill changed.

A few settlements have had their names changed when the U. S. Government established a post office and would not accept a name previously used for a post office elsewhere within the State. In some cases dual names persisted for some time, but eventually the village adopted the post office name.

In the list of family place names the great preponderance of German names is readily apparent and indicates the important part played by German immigrants in the early settlement of Lehigh County.

Family Names

Aimeyville
Alburtis
Allentown
Ballietsville
Bauer's Rock
Bests
Biery's Port
Billigs
Bittners Corner
Chapman Station
Claus(s)ville
Colesville
Coopersburg
Corning
Crane Station
Cranesville
Crowners Run
Custer(s)
Dallas Township
Deibertsville
Dillingersville
Dillingers Station
Donat Pig (Peak?)
Dorney Park
Dorney(s)ville
Eckert
Eisenhart
Fettersman Creek
Fogelsville
Fousts Ferry
Fryburg
Fullerton
Gauffs Hill

Germans Corner
Germansville
Greenawald
Griesemersville
Guths Station
Guthsville
Haafsville
Haas Hill
Haines
Hartzell
Hassen Creek
Helfrichs Cave
Hoffman
Holbensville
Hynemansville
Jeter Island
Kemmers
Kernsville
Kistler Run
Kline's Island
Krocksville
Kraussdale
Kuhnsville
Kunkle's Gap
Labarsville
Lake Thomas
Laros
Laury's
Leiberts Gap and Creek
Linnville
Linn Run
Lintzport
Litzenberg
Lynnville

Lynn Creek
Manoeys
Mary Ann Furnace
Merkle Station
Mickleys
Millerstown
Millers Island
Minnich
Mosserville
Myersville
Neffs
Neigharts Run
Newhard
New Smithville
Oppeltsville
Ormrod
Oswaldsville
Otts
Peters Store
Rabers Corners
Rextown
Ringers
Rittersville
Ruchsville
Rupps
Saegersville
Schadts
Schaefer Run
Schantzs Run
Scheidy
Schelly
S(c)herersville
Schnecksville
Schneidersville

S(c)hoenersville
Schrieber
Seiberlingville
Seiple
Seipstown
Siegersville
Siegfrieds Bridge
Sigmund
Smiths
Snydersville
Somerville
Stahlers
Steinsville
Stetlersville
Stines Corners
Switzer Creek
Thanys Creek
Treichlersville
Trexlertown
Truckers Creek
Walberts
Wallner
Walter Creek
Wanamaker
Weidasville
Weilersville
Wellington
Wennersville
Werleys Corners
Werleysville
Wescosville
Wilbur
Williamstown
Woodrings
Ziegler Run

3. *Foreign place names.*—Some Lehigh County places were named for foreign localities, usually the towns from whence the early settlers came. Here also most are of German origin, but there are several English and two Mexican:

Foreign Place Names

Hampton
Hanover
Heidelberg
Lanark
Lower Milford

Metamora
New Tripoli
Northampton
Salisbury (Salzburg)
Strassburg

Swabia Creek
Upper Milford
Vera Cruz
Weisenberg

4. *Domestic place names.*—A few places have been named for other localities within the United States. They are: Portland, Shocary Ridge, Texas, East Texas.

5. *Names of characteristic features.*—There has always been a tendency to name localities for some characteristic features either natural or man-made, or even some episode. In some case the particular feature may no longer persist. Some of these names may be inappropriate at the present.

Place Names Based on Characteristic Features

Allemängel
Bald Hill
Big Rock
Big Spring
Blue Mountain
Cavern Spring
Center Valley
Centerville
Clapboardtown
Crackersport
Crystal Spring
Fairview
Flats
Flint Hill
Fountain Hill
Grubsberg
Hilltown
Hosensack
Leather Corner Post
Lochland
Lowhill
Mountainville
Pleasant Corner
Rock Creek
Rockdale
Sandbank
Sand Spring
Sandstone Ridge
Sinking Run
Slate Dam
Slatedale
Slateville
Slatington
South Mountain
Spitzberg
Spring Creek
Spring Valley
Summit Lawn
Sunnyside
The Cove
Tunnel Hill

6. *Names of plants or animals.*—An abundance of some plant growth or some kind of animal life has furnished several place names in Lehigh County:

Floral Place Names

Cedarville
Cedar Creek
Cetronia
Chaperal Ridge
Cherry Ford
Chestnut Hill
Huckleberry Ridge
Laurel Hill
Locust Valley
Sprucetown
Waldheim Park
Willow Run

Faunal Place Names

Plover P. O.
Toad Creek
Trout Creek

7. *Names of occupations or industries.*—When certain occupations or industries are prominent they commonly are adopted as geographic place names. The mining and smelting of iron ore, once so important in the region, has furnished several names.

Occupational Place Names

Applebutter Hill
Furnace Hill
Iron Run
Ironton
Limeport
Mechanicsville
Mill Creek
Mill Hill
Minesite
Orefield
Powder Valley
Sideropolis

8. *Names of classes of people.*—Some place names indicate settlements of people with distinct characteristics. Several of this sort in Lehigh County are: Coffeetown, Hawktown, Indian Cave, Indian Creek, Indian Hole, Mingo.

9. *Biblical names.*—Although the early inhabitants were generally very religious, there are only a relatively small number of Biblical names in the region:

Adam(s) Island
Bethlehem
Egypt
Emmaus
Eve(s) Island
Jordan Creek, Village, etc.
Nain
Zionsville, Old Zionsville

10. *Fanciful and sentimental names.*—In almost every community there are a few place names that express the sentiments or fancies of the people who named them. These are of several sorts as indicated by the list:

Calypso
Emerald
Ferndale
Friedens
Friedensville
Rising Sun
Ruhetown
Standard

11. *Names of historic personages.*—Very few place names in Lehigh County were given in honor of historical characters who had no actual connection with the region. These are represented by Jacksonville, Washington Square, and Washington Township.

12. *Names for fancied resemblances.*—The weathering of the hard sandstones and conglomerates of Blue Mountain has given rise to some rock forms suggestive of different objects. Thus we have Bake Oven or Oven Knob, Bear Rocks, and Devils Pulpit.

13. *Miscellaneous place names.*—There remain a few place names not readily classified. We have Newside and Newtown, which express relative ages of the communities, Unionville for a union church, and Whitehall for a white residence.

PLACE NAMES IN LEHIGH COUNTY

Adam(s) Island, Allentown; one of the two islands in the Lehigh River between the Hamilton and Tilghman St. bridges named Adam and Eve.

Aineyville, Salisbury Township; named for the Ainey family. Is now part of South Allentown. Was also called Strassburg, probably because early inhabitants came from that city in Germany.

Alburtis, Lower Macungie Township; named for a railroad man when the East Branch of the Reading R. R. was built in 1857-58.

Alle-Mängel, Heidelberg and Lynn Townships; a name applied to the area embraced in Heidelberg and Lynn Townships and extending into Berks County. German words meaning "general destitution" or "lacking everything" especially roads, defense against the Indians, soil fertility, etc. In the early days the inhabitants of this section were in distress at times and required help. Has been written Alemingle, Allemeangel, Allamingle, Allamangle, Allemangel and Allemaengle.

Allen's Island—See Jeter Island.

Allentown; named for William Allen, the largest land owner of the region during the years of earliest settlement. He purchased a tract on which Allentown is situated, on September 10, 1735. On October 2, 1750 Allen was appointed Chief Justice of the Supreme Court of the Province. Allentown was first called Northampton or Northampton Town, although occasionally appearing on maps as "Allen's Town." Name was officially changed in 1838 to Allentown.

Applebutter Hill, Upper Saucon Township; named for a product extensively made by the residents of that section.

Bake Oven Knob, Heidelberg Township; named because the rocks of Kittatinny Mountain at that place bear a fancied resemblance to an old-fashioned bake oven.

Bald Hill, Upper and Lower Milford Townships; hill north of Hosensack, named for its appearance.

Ballietsville, North Whitehall Township; for Paulus Balliet who settled there in 1749 and later opened a hotel. A post office established there in 1826 was called North Whitehall; in 1876 was changed to present name of village.

Bauer's (Bowers) Rock, Upper Saucon Township; also called "Big Rock." Large rock on the top of South Mountain named for the Bauer family. In Davis' Atlas (1876) is called Prospect Rock.

Bear Rocks, Lynn Township; three large rocks on top of Kittatinny Mountain standing in a row near the junction of Lehigh, Schuylkill and Carbon counties. Said formerly to be the habitat of bears.

Best(s), Washington Township; a family name.

Bethlehem; partly included in Lehigh County. Original Moravian settlement, named on Christmas Eve, 1741, from birthplace of Christ in Judea, by Count Nicholas Ludwig von Zinzendorf. The Indians called the site of Bethlehem "Menagachsink" meaning "at the bending creek" probably with reference to the sharp turn of Monocacy Creek where it joins the Lehigh River.

Bethlehem Island; see Calypso Island.

Biery's Port; see Catasauqua.

Big Rock; see Bauer's Rock.

Big Spring; see Schantz's Spring.

Billigs; family name. See Litzenberg.

Bittners Corner, Lowhill Township; for the Bittner family who operated a mill there (on Mill Creek) for about 100 years (until 1890). The first of the family was Andrew (or Andreas) Bittner.

Blue Mountain, Lynn, Heidelberg, and Washington Townships; so named because of its bluish color when seen at a distance through a light haze. Also called Kittatinny Mountain, which see.

Bobst's Manor House; see Hynemansville.

Bogert Bridge, Salisbury Township; family name.

Breinig Run, Upper Macungie Township.

Breinigsville, Upper Macungie Township; for George Breinig who settled there in 1789.

Bridgetown, Hanover Township; name originally applied to East Allentown, located east of the Lehigh River bridge.

Buckhorn, Lower Milford Township; a hotel operated by George Stahl, prior to 1800, displayed a pair of elk antlers on a signpost to attract attention. See Hosensack.

Bull Head, Heidelberg Township; a prominent hill of Martinsburg sandstone and slate that vaguely suggests a bull's head.

Calypso Island, Salisbury Township; an island in Lehigh River at Bethlehem. Famous resort in early days. Originally called Catalpa Island because of the abundance of catalpa trees. Was later changed to Calypso probably because of its popularity for various kinds of diversions. In Greek mythology, Calypso was the daughter of Atlas and queen of the mythical island of Ogygia. There she entertained Odysseus for seven years. In Davis' atlas (1876) is spelled Galypso (probably a typographic error). About 1908 the south channel of the river was filled in and converted into a Lehigh Valley R. R. yard. On one map has been called Bethlehem Island.

Catasauqua Borough.

Catasauqua Creek, Hanover Township; a corruption of a Delaware Indian word, "Gottshacki" or "Gottoschacki," meaning "the earth thirsts for water," "parched land," or "dry ground" or "burnt ground." Name was probably applied to some place along Catasauqua Creek. The name was originally spelled "Catasocque." On Rogers' map the town is spelled Calesoque, and the creek Colesque. On Henry's map (1850) is written Gatasaquo. In early deeds is written Calisuk and Caladaqua. Early called Mill Creek because of number of mills.

Catasauqua was also called Biery's Port for Frederick and Henry Biery who came to that section early in the 19th century. When the Crane Iron Works were built it was for a time called Cranesville in honor of George Crane, a Welshman, who was associated with David Thomas in investigation of the use of anthracite in the blast furnace. "Sideropolis" meaning "Iron City" was suggested for the city and actually used for a time.

Cavern (Cave) Spring, Whitehall Township; a large spring (an underground creek) emerges from a cavern close to Jordan Creek north of Allentown. When the Jordan is in flood a considerable part of it passes through this hill by an underground route. Is also called Helfrich's Spring or Helfrich's Cave.

Cedarville; see Cetronia.

Cedar Creek, South Whitehall Township; named for cedar trees of the neighborhood.

Cementon, Whitehall Township; named because cement manufacturing is the principal industry of that locality. Was called Siegfried's Ferry and Siegfried's Bridge at an early date, these names applying to the settlements on both sides of the Lehigh River. For a time the railroad station was called Whitehall.

Center Valley, Upper Saucon Township; occupies a position near the center of the Saucon Valley in its longest dimension. Also spelled Centre Valley.

Centerville (Centreville), Lower Macungie Township; now the north part of the Borough of Macungie. See East Macungie.

Cetronia, South Whitehall Township; was also called East Macungie. When a post office was established here in 1888 the citizens proposed the name Cedarville which had long been used because of cedar trees in the region. The Post Office Department rejected the name and substituted Cetronia, the Latin word for cedar.

Chapperal Ridge, Upper and Lower Macungie Townships; a north-south hill between Ruppsville and Wescosville, formed by the terminal moraine of the Illinoian Ice Sheet. Named because of considerable brush and scrub growth on the hummocky, poorly drained moraine. A Mexican word.

Chapman Station or **Chapmans,** Upper Macungie Township; named for Charles W. Chapman, who was superintendent of the Catasauqua and Fogelsville Railroad. Previously called Sprucetown, probably because of spruce timber growing there.

Cherry Ford, North Whitehall Township; presumably named because of cherry trees in the vicinity.

Chestnut Hill, Lower Milford Township; the growth of chestnut trees furnished the name.

Clapboardtown, Whitehall Township; for a clapboard fence which Daniel Newhard erected about his home near Newhard's Mill, north of Allentown, in 1812.

Claus(s)ville, Lowhill Township; for David Clauss who ran a tavern there from 1834 to 1851.

Coffeetown, North Whitehall Township; probably a term of disrespect on account of the inhabitants who were considered by their neighbors as inferior.

Colesville, Upper Saucon Township; for the Cole family. Appears as Otts on an 1830 map by H. S. Tanner; probably a family name.

Coopersburg, Upper Saucon Township; for Daniel Cooper, a prominent early settler who located there before 1800, or for his son Peter Cooper, who was a Justice of the Peace and ran a hotel and store. Was also called Cooperstown. Was originally called Fryburg, Fryburgh or Frysburg for Joseph Fry who kept the village hotel.

Coplay, Whitehall Township.

Coplay Creek (also known as Indian Creek), Whitehall and North Whitehall Townships; Coplay takes its name from that of an Indian chief of the Shawnees (Shawanoes), Kolapechka (Kolapecha) (Copelin) who lived near the headwaters of the creek. He was the son of the Indian chief, Paxinosa. Erroneously it has been attributed to the Indian term "Copiechan" (Coplechan) meaning "a smooth or fine running stream." The village was long known as Schrieber from the ferry located here and operated by Daniel Schrieber. Has also been written Copley.

Corning, Lower Milford Township; named by the Railroad Company. Post office established in 1883.

Crackersport, South Whitehall Township; on account of a large supply of crackers having been stolen from a tavern at this place.

Crane Station, Upper Macungie Township; a station on the Catasauqua and Fogelsville branch of the Reading R. R. over which iron ore from mines near Fogelsville was hauled to the Crane Iron Works.

Cranesville; see Catasauqua.

Crowners Run, Heidelberg and Lowhill Townships; a name which appears on Rogers' 1858 map for the tributary of Jordan Creek now known as Mill Creek. Probably a family name. See Mill Creek.

Crystal Spring, Allentown; the spring along Little Lehigh Creek from which part of the water supply of the city is obtained. Named because of the clarity of the water.

Custer(s), Washington Township; small settlement. Probably a family name.

Dallas Township; see Washington Township.

Deibertsville, Heidelberg Township; for Daniel Deibert who ran a hotel and store here from 1842 to his death in 1881.

Devil's Pulpit, Washington Township; sandstone rocks on west side of Lehigh Gap resembling a pulpit; are probably across the county line and hence in Carbon County.

Dillingerville.

Dillinger Station, Lower Milford Township; for Dillinger family. John Jacob Dillinger purchased a property there in 1788 and erected an oil mill. Dillingers P. O. was first called Stahler's P. O. for Daniel Stahler, the first postmaster, receiving appointment in 1812. Dillingers Station was first called Schelly's Station for Levi N. Schelly who opened a store there in 1876.

Donat Pig (probably intended for Peak), Lynn Township; family name, given in Davis' atlas for high peak on Shochary Ridge close to the Berks County line. Also called Spitzberg (which see).

Dorney Park.

Dorney(s)ville, South Whitehall Township; for Peter Dorney who established a hotel here in 1871.

East Allentown, Hanover Township; founded in 1828. Became a part of Allentown in 1912. See Bridgetown.

East Macungie, Lower Macungie Township; was called Centreville (Centerville) because at an early date "every child of school age living in a radius of 2 miles was entitled to attend school free of charge."

East Fogelsville, Upper Macungie Township; about three-fourths mile east of Fogelsville, which see.

East Texas, Lower Macungie Township; was first called Macungie or Macungie Square, then Texas, later New Texas and in 1872 name changed to East Texas when a post office was established. Evidently named for the State of Texas. The generally accepted version of the name Texas is that it is an Indian word used as a token of friendship.

Eckert, Washington Township; for the Eckert family.

Egypt, Whitehall Township; so named because some of the early settlers likened the fertile soil along and near the Lehigh River to Egypt and the Nile. This similarity was strengthened by the fact that the residents of Alle-Mängel lying to the west had to come to this vicinity for provisions as Jacob's sons had to go to Egypt to buy corn. Was settled about 1733. Post office established in 1870.

Eisenhart; see Kernsville.

Emmaus, Upper Milford and Salisbury Townships; named by the Moravians in 1761 in memory of the little village of Emmaus in Palestine. Originally spelled Emmaus and occasionally written with one m with a straight line above, which was a shortened form used by the Germans. Later the superline was dropped by the Post Office Department. The map of Northampton and Lehigh Counties, Pennsylvania, 1830 by H. S. Tanner uses Emaus. When the spelling of the name with one m was first adopted is not known. H. D. Rogers in his Second Annual Report, 1838 (p. 20) gives "Emau's" and in his Fifth Annual Report, 1841 (p. 18) gives "Emaus." Spelling revised by the Post Office Department to Emmaus in 1938. The vicinity was formerly loosely called "Maguntchi" and "Salzburg."

Emerald, Washington Township; name chosen for post office at Franklin because no State is permitted to have two post offices by the same name and the name Franklin had previously been assigned.

Eve(s) Island, Allentown; see Adam(s) Island.

Fairview, Allentown; the pleasant view suggested the name. A part of South Allentown.

Farmington, name recently applied to a growing settlement in Salisbury Township. Farming on a small scale is carried on.

Fells Creek, North Whitehall Township; a family name. On some maps is called Rock Creek and Neigharts Run.

Ferndale; a picturesque appellation. See Fullerton.

Fettermans Creek; see Thanys Creek.

Five Points; see Guthsville.

Flats, Lower Macungie Township; a name applied to the rather flat area east of East Texas where several iron mines were once operated.

Flint Hill, Upper Saucon Township; named because of abundance of sandstone and quartzite cobbles in the soil. Has also been called Grub(b)sberg as the stones had to be grubbed (dug) out of the fields.

Flint Hill, Heidelberg Township; sandstone blocks of the Martinsburg formation are abundant.

Fogelsville, Upper Macungie Township; for Judge John Fogel, who built a hotel there in 1798, the first building in the place. Also spelled Foglesville. On an 1830 map by H. S. Tanner it is called Fogles. Post office was established in 1820.

Fountain Hill, Salisbury Township; so named because of springs in the upper part of the hill. In 1846 F. H. Oppelt established a "Hydropathic Institute" (commonly called a "water cure") at this place. The place was first called Oppeltsville. Town lots were laid out in 1854. In 1866 the present name was given by Tinsley Jeter.

Foust(e)s Ferry, Whitehall Township; a name appearing on a map about 1795. Located near present town of Coplay. Evidently a family name.

Franklin, Washington Township; probably named for Benjamin Franklin.

Freystown or **Freysburg,** Heidelberg Township; named for the Frey family, early settlers in Heidelberg Township.

Friedens; see Hoffman(s).

Friedensville, Upper Saucon Township; named for an old German church, "Friedenskirche" meaning "church of peace." Two settlements in Lehigh County bear this name. They are in Upper Saucon and Washington townships.

Frogtown; see Haafsville.

Fryburg; see Coopersburg.

Fullerton, Whitehall Township; for James W. Fuller who operated extensive iron works at the place. Was previously called Ferndale.

Furnace Hill, Upper Milford Township; Hampton Furnace, located at base of hill, was built in 1809 and is believed to have been the first one operated in Lehigh County.

Gauff Hill, Salisbury Township; family name.

Germans Corner, Heidelberg Township; for Henry A. German who started a store there about 1895. Located near the Lynn Township line about half a mile north of the railroad.

Germansville, Heidelberg Township; for Adam German, Sr., who was the original owner of land there, of which he obtained possession in 1742. Was originally known as German's Mill. Post office was established in 1828.

Green(a)wald, a suburb of Allentown; for A. M. Greenawald, who located there in 1882.

Griesemersville, South Whitehall Township; for Abraham Griesemer who built a hotel there in 1806. Now a part of Allentown.

Grouse Hall, South Whitehall Township; was the hunting lodge of Lynford Lardner. Evidently named because of the abundance of wild grouse. Name appears on early maps. See Whitehall Township.

Grubsberg; named because of the abundance of cobbles that had to be grubbed (dug) out of the fields. See Flint Hill.

Guths Station.

Guthsville, South Whitehall Township; for Lorenzo Guth (or Good), a German immigrant who settled there in 1739 and became a large land owner, or for his son Adam Guth who settled at the site of the town about 1780. Guthsville has also been called Five Points because of five roads leading outwards from the place.

Haafsville, Weisenberg and Upper Macungie Townships; for the Haaf family. Also called Frogtown or Bull Frog Town because of the presence of frogs.

Haas Hill or **Haas Knob,** Upper Macungie Township; for the Haas family. Written Haus on H. S. Tanner's 1830 map.

Haines, Upper Macungie Township; a family name.

Hampton.

Hampton Furnace; named for Hampton, England. See Sigmund.

Hanover Township; named for Hanover, Germany; the former home of many of the residents when (1798) the township was established.

Hartzell, Upper Macungie Township; for the Hartzell family.

Hassen Creek, Upper Macungie and South Whitehall Townships; should be Haas Creek. Named for Henry Haas who built a grist and flour mill there in 1795.

Haus, name appearing on Tanner's map (1830) in what is now Upper Macungie Township. Is probably intended for Haas.

Hawktown, Hanover Township; an old name applied to the east part of Catasauqua. A contemptuous term given because of undesirable inhabitants.

Heidelberg Township; so named because of early settlers from the vicinity of Heidelberg, Germany. Township erected in 1752. Also written Heydelberg.

Helfrich's Cave, Whitehall Township; a small cave from which issues a large amount of water (Helfrich's Spring). Has also been called Indian Cave. See Cavern Spring.

Helfrich('s) Spring, Whitehall Township; for the Helfrich family that once owned it. See Cavern (Cave) Spring. At different times received the names of other owners. Thus it has been called Grim Spring and Blank Spring.

Helfrichsville, family name formerly applied to a small cluster of homes in south corner of Weisenberg Township.

Hensingersville, Lower Macungie Township; for Peter Hensinger, who built a hotel there in 1846. Also written Hensenger.

Hillside, South Whitehall Township; small settlement on side of hill.

Hilltown, Allentown; name once applied to a small settlement about three-fourths mile south of Wennersville, because near a small hill.

Hoffman (Hoffmans), Washington Township; for Francis Hoffman, one time postmaster. The village is known as Friedens or Friedensville from the Friedens (Peace) Church located there.

Hoffmansville; see Kernsville.

Hokendauqua, Whitehall Township; corrupted from Hakiundochwe, an Indian term signifying "searching for land." Was formerly "Hockquandauquoa." It is thought that perhaps the Indians gave the name when they observed some surveyors at work. First applied to stream. Other spellings found on maps are:

Hockandauqua
Hockendauqua
Hockendauquo
Hockendock
Hockendocque
Hockendoque
Hockendoquo
Hockiundaqua
Hockway and Dockway
Hockyondocquay
Hockyondoque
Hocqueondocy
Hokendauqua
Hookiendocque
Hookyondocque
Hoquendoquy

Holbensville; see Pleasant Corners.

Hosensack.

Hosensack Creek.

Hosensack Hill, Lower Milford Township; it is said that the early German surveyors compelled to "return from the valley by the same route taken in entering it" gave the name of Hosensack (pants pocket). Another explanation is that some German travelers compelled to spend a night in the valley remarked that "es war so dunkel wie in einem hosensack" (It was as dark as in a pants pocket). The village was earlier called Buckhorn. In Rogers' Third Annual Report (p. 21) it is written "Hosacock" and the same name appears on H. S. Tanner's map published in 1830.

Huckleberry Ridge, South Whitehall Township; presumably named because of the huckleberry bushes found there.

Hynemansville, Weisenberg Township, for Frederick Hyneman who ran a store at the place about 1800. Founded about 1740 by Michael Bobst who had a tavern and store there and for some time was known as Bobst's Manor House. Also spelled Heinemansville.

Indian Cave; see Helfrich's Cave.

Indian Creek, Upper Milford Township; named for the early inhabitants of the region. Coplay Creek was also at one time known as Indian Creek.

Indian Hole, South Whitehall Township; a large limestone sinkhole east of Guthsville and near Huckleberry Ridge where an Indian princess is said to have lived. Numerous Indian arrow heads and flakes have been found nearby.

Iron Run, Upper Macungie Township; named because of old iron mines near the head waters.

Ironton, North Whitehall Township; named for the iron mines opened there in 1835. Post office was established in 1860.

Jacksonville, Lynn Township; for President Jackson. Named in 1845.

Jeter Island, Salisbury Township; for Tinsley Jeter, a prominent citizen of Bethlehem. Was also called Allen's Island for William Allen. See Kline's Island.

Jordan Bridge, South Whitehall Township.

Jordan Creek, Heidelberg, Lowhill, South Whitehall and Whitehall Townships.

Jordan Valley, Heidelberg Township.

Jordan (or Pleasant Corners), Heidelberg Township; for the Jordan River, Palestine, by early settlers. Jordan Creek is called Trucker's Creek on some old maps. A mill on Trout Creek appears on old maps as Trucker's Mill. Trucker supposedly is a family name although Richards (1896) says it was a nickname applied to William Kern who ran the mill. He was said to be a joker or wit, trockener in German. This in time was corrupted to Trucker. In some old deeds it is called Indian Creek. See Pleasant Corners.

Kemmerer's Inn; see Laros.

Kernsville, North Whitehall Township; for Peter Kern, who built a stone grist mill there in 1806. Has also been called Hoffmansville for John Hoffman, who built a hotel there. Post office established in 1833 was called Kern's Mill, changed in 1849 to Eisenhart, a family name, and in 1850 to Orefield (which see).

Kistler Creek, Lynn Township; for the Kistler family, early residents of Lynn Township. George Kistler is said to have settled there between 1735 and 1745.

Kittatinny Mountain, Lynn, Heidelberg and Washington Townships; a corruption of the Indian name "Kantatinchunk," meaning "the main or principal mountain." Also said to have been derived from the Indian term "Kekachtauanim" meaning "endless mountains." See Blue Mountain. On a 1752 map is written "Kekaghtenemin or Blue Mountain."

Kline's Island, Salisbury Township; for the one-time owner, Charles Kline. Was earlier called Lehigh Island. See Jeter Island.

Kraussdale, Lower Milford Township; for Bal(t)zer Krauss, Jr., who donated the land for a Schwenkfelder church. He purchased a farm there in 1793. Located about 2¼ miles south of Hosensack. Also spelled Krausedale.

Krocksville, Upper Macungie Township; family name.

Kuhnsville, Upper Macungie Township; for the Kuhns family.

Kunkle's Gap; a family name. See Lehigh Furnace Gap.

Labarsville; see Slatedale.

Lake Thomas, Upper Saucon Township; an old iron mine formerly worked by the Thomas Iron Co.

Lanark, Upper Saucon Township; for a small village near Glasgow, Scotland.

Laros, Upper Macungie Township; for Henry Larosch who operated a tavern at that place. It was also known as Kemmerer's Inn.

Laurel Hill, Whitehall Township; name given to the shale hill northwest of Cementon presumably on account of a growth of laurel.

Laurys Station, North Whitehall Township; for Judge David Laury who erected a hotel there in 1832. Previously known as Slate Dam because of a dam built there in 1830 by the Lehigh Coal and Navigation Co.

Leather Corner Post, Lowhill Township; a fantastic name given to a tavern built at this place before the Revolutionary War. Said to have been given on account of a side of leather nailed to a post being stolen and later returned. On an 1830 map by H. S. Tanner the place is called Woodrings.

Lechauweki Springs, Salisbury Township; springs at south side of Fountain Hill. See Lehigh River for derivation of term.

Lehigh Church; see Weilersville.

Lehigh County; organized from part of Northampton County on March 6, 1812.

Lehigh Furnace, Washington Township; name of a furnace erected in 1826 and supplied with ore from Ironton. Also called Balliet's Furnace.

Lehigh Furnace Gap, Washington Township; in Blue Mountain north of Lehigh Furnace. On Tanner's 1830 map it is named Kunkle's Gap.

Lehigh Gap, Washington Township; gap in Blue Mountain made by Lehigh River. The Indian name was "Buchkabuchka" meaning "mountains butting opposite each other."

Lehigh Island; see Kline's Island.

Lehigh Mountain; see South Mountain.

Lehigh River; named by Delaware Indians Lechauwe(e)ki (Lechaweki, Lechauwiechink, Lechauwekink, Lechaweing), "where there are forks" or "the fork of a road," of which the present name is a corruption. Heckewelder states "this name was given to the River, because through it struck an Indian path or thoroughfare coming from the lower part of the Delaware country, which thoroughfare, on the left bank of the river *forked off into various trails*, leading North and West." Other writers believe that the name was given because of the stream being a fork of the Delaware River. Was originally called the West Branch of the Delaware. Also called Great Lechau (in distinction with the Little Lechau (Lehigh), Lecha, Lechaw, Leckhaw, Lechay, Lechy, Leckauwak, Lehi, Lehy and Leighy. On most of the maps prepared between 1750 and 1800 it is written Lecha. Germans shortened Indian name to Lecha and English adopted present form.

Leiberts Creek, Upper Milford Township.

Leiberts (Leiperts) Gap, Upper Milford Township; family name. Gap through South Mountain through which Leiberts Creek, a tributary of Little Lehigh Creek, passes.

Limeport, Upper Saucon and Lower Milford Townships; named for the lime kilns which from 1850 to 1885 were operated here.

Linnville.

Linn Run; name applied to Switzer Creek on Rogers' 1858 map. See Lynn.

Lintzport; a small settlement and hotel in Lynn Township about a mile south of Lynnville. Probably same derivation as Lynn. See Stine's Corner.

Little Cedar Creek, Upper Macungie and South Whitehall Townships; a tributary of Cedar Creek. See Cedar Creek.

Little Lehigh Creek, Lower Macungie and Salisbury Townships; a large tributary of Lehigh River. See Lehigh River. One of the sources of Little Lehigh Creek at Trexlertown was named Tuppechhanna, meaning "the stream that flows from a large spring." On Lewis Evans' map (1755) the creek is named "Lexey." Also appears as Lehi Creek.

Little Run Junction, Washington Township; stream junction.

Little Trout Creek, Heidelberg and Washington Townships; the stream contained many trout, hence the name.

Litzenberg, Upper Macungie Township; family name. Appears as Billigs, a family name, on 1830 map by H. S. Tanner.

Locust Valley, Upper Saucon Township; probably named because of locust trees growing there.

Lochland, Lynn Township; hills probably suggested Scottish scenery.

Lock Ridge (Lockridge), Lower Macungie Township; named for the Lockridge iron furnace operated there.

Lower Macungie Township; see Macungie.

Lower Milford Township; name probably derived from Milford, Connecticut but possibly from Milford, Wales or Milford, England.

Lowhill, Lowhill Township.

Lowhill Township; it has been suggested that the name was applied because of numerous hills of low elevation.

Lynn Township.
Lynnport, Lynn Township.
Lynnville, Lynn Township; for Jacob Lynn (Linn), one of the first settlers who lived near the base of Blue Mountain. Also spelled Linn on old maps. Roberts thinks it was named for Lynn, Mass. as the Everett family, early settlers, came from Massachusetts.

Lyon Creek, Weisenberg and Lowhill Townships; family name, also erroneously written "Lion."

Lyon Valley, Lowhill Township; family name. Called Willow Run on Tanner's 1830 map and on Rogers' 1858 map. Post office was established in 1857.

Macungie, Lower Macungie Township; "Mauck-Kuntshy" is an Indian name signifying "eating place of bears" because bears would come down in the valley when food in the mountains was scarce. The name seems to have first been applied to the present site of Emmaus. It was at one time called Millerstown (Miller's Town) or Millersville after Peter Miller who founded it in 1776. Also spelled Machk-unschi, Machts Kunshi, Machts Kunski, Macongy, Maccongy, Macungy, Macunjy and Maguntsche.

Macungie Square; see East Texas.

Manoeys, Weisenberg Township; small settlement in the southeast corner of Weisenberg Township, about 2½ miles southeast of New Smithfield. Appears on an 1830 map by H. S. Tanner as Maoeys.

Mary Ann Furnace; see Sigmund.

Mechanicsville, South Whitehall Township; named because of a carriage factory owned by John Scheetz located there employing a number of hands (mechanics).

Merkle Station, Lower Macungie Township; family name.

Metamora Siding, South Whitehall Township; evidently from Metamoros, Mexico. Name probably applied about the time of the Mexican War.

Meyersville, South Whitehall Township; see Myersville, the former name.

Mickleys, Whitehall Township; named for the Michelet (Mickley) family. Jean Jacque Michelet (John Jacob Mickley) a Swiss immigrant, settled on Mill Creek in 1745. The name was early changed to its present form.

Mill Creek, Heidelberg and Lowhill Townships; the use of water power for mills is responsible for the name. See Crowners Run. Catasauqua Creek was also at one time called Mill Creek.

Millers Creek, Upper Milford and Lower Macungie Townships; family name. Rises near Shimersville, flows northward into Little Lehigh Creek.

Millers Island; family name applied to a small alluvial island in Lehigh River south of Slatington.

Millerstown; see Macungie.

Mill Hill, Lowhill Township; high hill between Mill and Jordan creeks. Named because of proximity to Mill Creek.

Minesite, Lower Macungie Township; named because of iron mines once worked in the vicinity.

Mingo, Hanover Township; name applied to East Allentown because negroes from Santo Domingo lived there.

Minnich, South Whitehall Township; a family name.

Monocacy Creek, Hanover Township; corrupted from *Managassi*, *Menagassi*, or *Manakessi* signifying "a stream with several large bends." *Managachsink* was the name given by the Delawares to the site of Bethlehem at the mouth of the creek. The following are the various other spellings found in old records and on old maps:

Manacassee
Manakasie
Manakasy
Manakesey
Manakesie
Manakesy
Manakisy
Manocacy
Manockisy
Manokacey
Manokasy
Manokesy
Manookisy
Manoquesy
Menagassi
Menakasie
Menakasy
Monakasy
Monakisy
Monacacy
Monacasy
Monocasy
Monocaisy
Monockacey
Monockicey
Monockisy
Monockozy
Monokasie
Monokasy
Monokesey
Monokesy
Monokessy
Monokisy
Monokissy
Monokosey
Monoquacy
Monoquasy

Mountainville, Salisbury Township; so named because of its location at the foot of South Mountain. Was called Smith's from Rudolph Smith who had a hotel there during the Revolution.

Mosserville, Lynn Township; for Philip Mosser who purchased property there in 1763, or for his sons. Post office was established in 1857.

Myersville, South Whitehall Township; a family name.

Nain, Hanover Township; village built for the converted Indians by the Moravians at the suggestion of Count Zinzendorf. Named by the Count for the Biblical village of Galilee. Was located just north of the west part of Bethlehem, and occupied from 1758 to 1763.

Neffs (Neffsville), North Whitehall Township; for Abraham Neff who made coaches there for some years and laid out the village in 1810. Post office established in 1860. Has also been written Neefsville.

Neigharts Run; see Fells Creek.

Newhard (Newhards), Washington Township; a family name. In a general map of Lehigh County, Davis (1876) names this place Treichlersville, for the Treichler family. On H. S. Tanner's 1830 map is written Neiharts.

Newside, Washington Township; named by the proprietor of a hotel located there. Was earlier called Washington Square, which was founded by Nathan Peter in 1850.

New Smithville, Weisenberg Township; for Solomon Smith who ran a hotel at the place. In 1830 a post office here was called Weisenberg.

New Texas; see East Texas.

New Tripoli, Lynn Township; named in 1816 to commemorate the success of the U. S. Navy in its war against Tripoli.

Newtown, Upper Macungie Township; named because of its more recent settlement relative to other villages of the county.

Northampton (Northampton Town); see Allentown.

North Whitehall; see Ballietsville and Whitehall.

North Whitehall Township; see Whitehall.

Old Zionsville, Upper Milford Township; was given the biblical name because of an early church built there. Was first called Zionsville but changed to its present name when a new village by that name was built along the railroad. Post office established in 1849.

Ontelaunee Creek, Lynn Township; also spelled Antelauna, Antalaunee and Antelawny. An Indian name meaning virgin or maiden. In Berks County the creek is called Maiden Creek.

Oppeltsville (Oppeldtsville); see Fountain Hill.

Orefield, South Whitehall Township; named because of the iron ore deposits in the region. See Siegersville and Kernsville.

Ormrod, North Whitehall Township; for George Ormrod who was one of the organizers of the Lehigh Portland Cement Co. The settlement was started in 1898.

Oswaldsville, Lynn Township (Raber's Corners); a small settlement about a mile west of New Tripoli. Named for Jonas Oswald who built a hotel there about 1860. A post office was in existence there in 1878.

Otts; see Colesville.

Oven Knob; see Bake Oven Knob.

Perkiomen Creek, Upper Milford Township; from the Indian word "Pakiomink" meaning "where there are cranberries."

Peters Foundry, Washington Township.

Peters Store, Washington Township; for the Peters family. Casper Peters settled in the region in 1742.

Pleasant Corner(s), Heidelberg Township; originally named Holben(s)ville for Jacob Holben who erected a foundry there in 1850. It was changed to its present name by Owen Hunsicker, Daniel Rex and Abraham Peter because of its desirable location, about 1857. The first post office there, established in 1873, was called Jordan Post Office.

Plover, Lower Milford Township; a post office maintained under this name from 1890 to 1905, was located east of Dillingerville on the road to Steinsburg a short distance southeast of Hosensack Creek. Evidently named for the bird.

Portland, Whitehall Township; site of Coplay Cement Co.'s works where the first portland cement of the region was made.

Powder Valley, Upper Milford Township; named because a powder mill was erected in the valley in 1829 by Henry Kemmerer.

Raber's Corners; family name. See Oswaldsville.

Reitz, Lynn Township; for Jonas Reitz who operated a mill and distillery on Ontelaunee Creek.

Rextown, Washington Township; probably named for Henry Rex who was born in Washington Township in 1798.

Ringers, South Whitehall Township; a family name.

Rising Sun, North Whitehall Township; a picturesque name selected by residents. Store and hotel built here in 1860.

Rittersville, Hanover Township; derives its name from Michael Ritter who opened a tavern there in 1808. Later operated a store at the place. Now a part of Allentown.

Rock Creek; see Fells Creek.

Rockdale, North Whitehall Township.

Rockdale Creek, North Whitehall Township; originally called "The Sandbank" because of good sand obtained there. Changed to Rockdale in 1856 by Robert H. Sayre because of high slate bluffs.

Ruchsville, North Whitehall Township; for Gen. Peter Ruch, a militia officer who ran a hotel there. Post office was established in 1844.

Ruhetown, Lowhill Township; a small cluster of houses along Jordan Creek in southeastern Lowhill Township. So named because several retired farmers lived there seeking rest (ruhe).

Rupps (Ruppsville), Upper Macungie Township; for the Rupp family. George Rupp, the ancestor, came from Germany and settled there at an early date.

Saegersville, Heidelberg Township; for Nicholas Saeger who purchased the land in 1806 and deeded it to his son Joseph Saeger in the following year. Post office was established in 1828. Also written Seagersville and Segersville.

Salisbury Township; there are different ideas regarding the name. May have been named for Salisbury, England. As it was settled by Germans, it was more probably named for Salzburg (Salzbury) in Bohemia from which some of the early settlers came. The name appears occasionally as Salsberg, Salsburg, Saltzberg, Saltzburg, Saltzbury, Salzburg and Salzbury. Statement has been made that it was intended to have the German form but the County Clerk, an Englishman, wrote it Salisbury (or salisburg) by mistake. Named in 1753.

Sandbank; see Rockdale.

Sand Spring, North Whitehall Township; a large spring half a mile east of Schnecksville in which the water bubbled up through sand. An Indian chief was said to have had a home there. Also called Wotring's Sand-Spring from nearby Wotring's mill.

Sandstone Ridge, North Whitehall Township; a ridge north of Rockdale Creek in which sandstones of the Martinsburg formation are prominent. A similar ridge south of Newhard in Washington Township has received the same name.

Saucon Creek, Upper Saucon Township.

Saucon Hill.

Saucon Station, Upper Saucon Township; Saucon is a corruption of an Indian name "Sakunk" which was applied to an Indian village or place occasionally occupied by Indians near the mouth of Saucon Creek. It is derived from "Sa-ku-nit" meaning "the mouth of a creek."

Schadts, North Whitehall Township; a family name.

Schaef(f)er Run, Upper Macungie Township; a family name.

Schantz Hill, North Whitehall Township; a prominent hill west of Schnecksville. A family name.

Schantz's Spring, South Whitehall Township; a large spring that furnishes water for City of Allentown. Was in possession of Schantz family for many years. In the early settlement of the region it was called Big Spring.

Scheidy, North Whitehall Township; a family name.

Schelly's Station; see Dillinger Station.

Scherersville (Sherersville), South Whitehall Township; for John Scherer, who built a hotel here in 1837.

Schneckville, North Whitehall Township; for Daniel Schneck who laid out the village about 1840. Post office was established in 1846. Adam Schneck settled here in 1766.

Schneidersville, Lynn Township; a family name. Name appears in Davis' atlas (1876). Located about three-fourths mile northwest of Lintzport (Stines Corner).

Schoenersville; see Shoenersville.

Schrieber; see Coplay.

Seiberling(s)ville, Weisenberg Township; for Joshua Seiberling, who opened a store there in 1836 and was the first postmaster in 1841.

Seigersville; see Siegersville.

Seiple (Seiple's Station), Whitehall Township; named in 1857 for Jacob Seipel, who ran a hotel at the place.

Seipstown or **Seipsville,** Weisenberg Township; founded by Melchior Seip who came from Wurtemberg before 1747 and settled a few miles from present village. Hotel was built there in 1825.

Sherersville; see Scherersville.

Shimerville, Upper Milford Township; for John Shimer who ran a tavern there from 1792 to 1828. Spelled Sheimersville on Rogers' 1858 map. Also spelled Scheimersville and Shimersville.

Shochary Ridge, Lynn and Heidelberg Townships; for Schoharie in New York State, the former home of some of the early settlers. The incorrect spelling has become fixed. See Spitzberg.

Shoenersville, Hanover Township; for Adam Schoener, who settled there in 1784. He operated a tavern known as "Blue Ball."

Sideropolis; see Catasauqua.

Siegersville, North and South Whitehall Townships; for Melchior Sieger who settled there about 1750. Post office established in 1833. Name later changed to Orefield (which see). Also written Seigersville.

Siegfrieds Bridge.

Siegfrieds Ferry; see Cementon.

Sigmund, Upper Milford Township; for Frederic Sigmund who ran the Hampton Furnace, earlier known as the Mary Ann Furnace and later called Sigmund's Furnace. On some maps is called Hampton.

Sinking Run, Upper Macungie and South Whitehall Townships; name applied to a small stream northeast of Fogelsville that disappears underground. (Maps of H. D. Rogers, 1858, and of H. S. Tanner, 1830.)

Slate Dam; see Laury's Station.

Slatedale, Washington Township.

Slateville, Lynn Township.

Slatington, Washington Township; because of the slate quarries of the region. Slate was first quarried here in 1848 (1845?). Slatedale was formerly known as Labarsville, from George and Nelson Labar who owned the land upon which the village stands.

South Allentown; for its location. Once a separate borough now a part of Allentown. See Aineyville.

Smith's; see Mountainville.

Snydersville, South Whitehall Township; for George Snyder who was known as the "keeper of the Drovers' Inn." On Rogers' 1858 map is called Somerville, presumably a family name. Has also been called Sunnyside.

Somerville; see Snydersville.

South Mountain, Salisbury, Upper Saucon and Upper Milford Townships; named because of position on south side of the great limestone valley. Also called Lehigh Mountain. Is a part of the Durham and Reading Hills. Lewis Evans called it the "Lexey Hills."

South Whitehall Township; see Whitehall.

Spitzberg (Spitzburg) Hill, Lynn Township; so named because of the sharp point (spitz) on Shochary Ridge at county line. Also called Donat Pig (which see).

Spring Creek, Lower Macungie Township.

Spring Creek, Whitehall and North Whitehall Townships; numerous springs furnish the name. Has also been known as Spring Mill and Spring Mills Creek.

Spring Valley, Upper Saucon Township; a large spring gives the name.

Sprucetown; see Chapmans Station.

Stahler's P. O.; see Dillingersville.

Standard, Upper Saucon Township; post office maintained from 1893 to 1904. Name expresses local pride.

Steinsville, Lynn Township; for Michael Stein to whom the land was granted by warrant about 1756.

Stet(t)lersville, South Whitehall Township; for Daniel Stettler, an early resident.

Stines (Steins) Corner, Lynn Township; named in 1874 for William Stein. In Davis' atlas (1876) it is called Lintzport.

Strassburg; see Aineyville.

Summit Lawn, Salisbury and Upper Saucon Townships; from position on top of South Mountain. Named by the Reinbold family about 1900.

Sunnyside; see Snydersville.

Swabian Creek, Lower Macungie Township; for Swabia in southern Germany where many of the early settlers were born. In Davis' atlas is called Swope Creek. Seems to be the stream called Swamp Run on a map drawn in 1759.

Switzer, Weisenberg Township.

Switzer Creek, Lynn and Lowhill Townships; originally written Sweitzer. Name given because of many Swiss settlers on the head waters. On Rogers' 1858 map the creek is called Linn Run.

Texas, Lower Macungie Township; see East Texas.

Thanys Creek, Upper Milford Township; rises near Shimerville, flows eastward and empties into Leiberts Creek near Vera Cruz. Also called Fettermans Creek. Both are family names.

The Cove, Upper Macungie Township; a flat area west of Fogelsville enclosed on three sides by slate hills.

Toad Creek, Lower Macungie Township; a small west tributary of Little Lehigh Creek. Presumably named because of numerous toads in the vicinity.

Treichlersville; see Newhard.

Trexler County Game Preserve, North Whitehall and Lowhill Townships; a game park southwest of Schnecksville established by Col. Harry C. Trexler in 1906 and given to Lehigh County in his will.

Trexlertown, Upper Macungie Township; for the Trexler family. Jeremias Trexler located there in 1719.

Trout Creek, Heidelberg and Washington Townships; named because it was once a good trout stream.

Trout Creek, Salisbury Township; a tributary of Lehigh River north and northeast of Mountainville. Unnamed on most maps. Presumably once contained trout.

Trucker's Creek; see Jordan Creek.

Tunnel Hill, Upper Milford Township; for a Reading Railroad tunnel south of Vera Cruz.

Tuppeckhanna; see Little Lehigh Creek.

Unionville, North Whitehall Township; for a Union Church located there. It is a part of Neffs.

Upper Macungie Township; see Macungie.

Upper Milford Township; see Lower Milford.

Upper Saucon Township; see Saucon.

Vera Cruz, Upper Milford Township.

Vera Cruz Station, Upper Milford Township; named for Vera Cruz, Mexico in 1851 by Alexander Weaver, a storekeeper here.

Walberts, South Whitehall Township; for Solomon Walbert, who ran a tavern there. Post office was established in 1857.

Waldheim Park, Salisbury Township; translation of name is "forest home." A park on the slope of South Mountain near Mountainville, controlled by the United Evangelical Church.

Wallner, Upper Macungie Township; a family name.

Walter Creek, Lower Milford Township; a tributary of Hosensack Creek. A family name.

Wanamaker, Lynn Township; for the Wanamaker (Wannemacher) family, a member of which located there before 1740.

Washington Square; see Newside.

Washington Township; for George Washington. Was set up in 1847. Originally was a part of Heidelberg Township and first called Dallas Township but changed during first year to present name.

Weidasville, Lowhill Township; for the Weida family. Peter Weida purchased 200 acres there in 1811 and built a grist mill in 1840 which was operated by his sons for 50 years. Post office was established in 1863. Has also been written Wydasville.

Weilersville, Lower Macungie Township; for James Weiler, who had a store there about 1840. Was also known as Lehigh Church.

Weis(s)enberg, Weisenberg Township.

Weis(s)enberg Township; named in 1753 for a fortress and town, Weisenberg (white castle), in Alsace from which place many of the early residents came. Also see New Smithville. Also spelled Wisenburgh, Weissenburg and Weissenburgh.

Wellington, Whitehall Township; family name.

Welshtown (Welchtown); small settlement north of Slatington along Slatington-Rextown road. Originally occupied by Welsh slate workers.

Wennersville, South Whitehall Township; located on the farm of George Wenner. His son William opened a hotel there in 1837.

Wereleys Corners (Werleysville, Wereleys), Weisenberg Township; for Elias Wer(e)ley, who operated a store there.

Wescosville (Wescoeville, Wescoesville), Lower Macungie Township; for Philip Wesco(e), who kept a wayside inn here in 1828, or for his son, Israel Wesco(e), who kept the tavern and was appointed the first postmaster in 1844.

West Catasauqua, Whitehall Township; across Lehigh River from Catasauqua. See Catasauqua.

West Coplay, Whitehall Township; see Coplay.

Whitehall; see Cementon.

Whitehall Township; Lynford Lardner owned a tract of land between Cedar and Jordan creeks on which, about 1740, he erected a residence, which he named Grouse Hall. Painted white, it became known as White Hall. This name was adopted for three townships. Roberts states that the name was selected in 1753 by English officials after Whitehall, England.

Wilbur, Salisbury Township; family name.

Williamstown, Washington Township; for Henry Williams who built a Welsh Baptist church here in 1862.

Willow Run, Low Hill and Weisenberg Townships; probably named because of willow trees growing there. See Lyon Creek.

Ziegler (or **Ziegel) Knob** (or **Hill),** Upper Macungie and Weisenberg Townships; a family name given to the shale ridge north of Newtown.

Woodrings; see Leather Corner Post.

Zionsville, Upper Milford Township; a new village started after the building of the railroad. See Old Zionsville.

WEATHER AND CLIMATE

By Benjamin L. Miller

At the outset it may be well to distinguish between weather and climate as the two are frequently confused. Briefly, weather is the combination of all the meteorological elements—atmospheric pressure, temperature, precipitation, wind, humidity, degree of cloudiness, etc.—at some particular time; whereas climate is the average of weather conditions over considerable time. The distinction has been expressed in the statement that "weather is a passing phase of climate." For most of our daily activities we are primarily interested in the weather, but for the determination of a certain place as a desirable locality for specific industries, for certain agricultural crops, or for agreeable living conditions, we are far more concerned with climate. In most places weather conditions vary from day to day, whereas changes of climate are so slow that ordinarily they are not prominently noticeable even within a life time.

Both climate and weather are of extreme importance and ever-increasing interest to persons everywhere. This is, in part, attributable to mere curiosity but, in most instances, has a definite economic bearing in countless ways. The first thought on awakening in the morning concerns the weather, and the weather prediction for the day is generally almost the first item read in the morning newspaper.

The writer, who has had charge of the meteorological equipment in Lehigh University since the installation in 1925, has had abundant illustrations of the importance of weather data in the Lehigh Valley. The records have been studied by fuel companies, by liability insurance companies, by highway and building construction companies, by various manufacturing concerns, and by industries seeking new locations. Many Court cases require meteorological data for a wide variety of reasons. At present certain industries are as dependent upon weather as is agriculture.

The whole field of air-conditioning, so rapidly expanding, has been developed in comparatively recent years as scientific investigations have shown the importance of uniform weather conditions for the comfort and efficiency of the workers and the superiority of the products. Of course, air-conditioning has its limitations and is not applicable to general agricultural pursuits and to most of the heavy industries; in the main we must live under natural weather conditions.

The ideas of climate and weather held by some people are woefully erroneous, based as they are on inaccurate observations and on faulty recollections, which almost invariably recall the unusual events and omit the normal occurrences. The belief in former greater extremes is almost universal among old people in any community, regardless of the fact that over and over again it has been shown by instrumental readings and carefully recorded observations of trained meteorologists that there is little or no basis for such conclusions. An examination of the data presented in the following pages should disprove the common belief in definite trends in any one direction sufficient for one to forecast conditions in succeeding seasons. It is doubtful whether anyone will be able to note recurring cycles of the elements which make up our climate and weather.

The most valuable studies of weather and climate must be based on statistics. Meteorological conditions that have occurred at one time may recur, and when many years are involved the reasonable assumption is that all types of weather that may ever be expected will be represented. For such studies the longer the records the more dependable are the conclusions. Each year is different and yet the variations from the average are seldom of marked degree. It is true that every few years some meteorological record is broken in each community, but if 50 or more years of records are available one may be fairly certain that the extremes will not vary materially from extremes previously recorded.

As shown on the following pages, records of Lehigh County weather are available for a fairly long period of time, yet much longer records would be highly desirable. Longer and more complete records have been made for Philadelphia and Reading. In the Northampton County report * the writer included data from nearby stations, but in this volume records from Lehigh County localities only are used. An exception is that some gaps in records are filled by data from adjoining counties.

The weather elements noted and each observer's length of service are given in the table below, as far as the records are preserved. Nearly all the observations were taken either wholly or in part with instruments furnished by the U. S. Weather Bureau, and most of the original records are preserved in the Philadelphia or Harrisburg office of that organization. Duplicate records are on file also at the respective stations where meteorological observations are still being made. Much of the available data is contained in the publications of the U. S. Weather Bureau, mainly in the monthly reports and annual summaries of Climatological Data, Pennsylvania Section, which are preserved in many libraries.

All the observational data used were taken according to the regulations of the U. S. Weather Bureau. These observations are frequently greatly at variance with those given by local papers and passed about by word of mouth. The extreme temperatures of summer are almost invariably lower than those recorded by the ordinary thermometers on the street level or where they are not properly shielded from the direct rays of the sun. The winter extremes, likewise, are apt to be higher than those recorded by poor or improperly placed thermometers.

The U. S. Weather Bureau gives specific instructions for the installation of the instruments. Naturally, only the data obtained under the same standard conditions are exactly comparable. The miscellaneous precipitation data of untrained observers are more reliable than temperature records, but they, too, may be inaccurate, and, therefore, some available information has been ignored in the prep-

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* Miller, B. L., Northampton County, Pennsylvania: Pa. Topog. and Geol. Survey, 4th ser., Bull. C-48, pp. 74-114, 1939.

aration of this report. A mass of unorganized meteorological data might be collected from the files of newspapers and other publications of the Lehigh Valley.

In the discussion of the weather and climate of any locality many different elements or factors are worthy of consideration. Obviously, in a volume of this character, it is impossible to treat more than a few of these, even where records are available. The ones selected are maximum, minimum, and mean temperatures, frost, precipitation (both rain and snow), relative humidity, winds, and descriptions of storms that pass through the Lehigh Valley.

Official meteorological observations in Lehigh County

Duration	Elements	Observer
	Allentown	
Jan. 1912-Dec. 1920	Monthly precipitation.	?
Mar. 1922 to date	Temperature — maximum, minimum, etc., precipitation, prevailing wind, direction, character of day.	John A. Frick
	Coopersburg	
Jan. 1890-Dec. 1900	Monthly mean temperature and precipitation.	?
	North Whitehall and Egypt	
Jan. 1856-Apr. 1881	Monthly mean temperature.	? Made for the Smithsonian Institution.

Mean Temperature

For purposes of comparison mean temperatures are perhaps more important than maximum and minimum temperatures. The mean daily temperature, as given in the official records of the U. S. Weather Bureau, is the average of the daily maximum and the daily minimum, and the mean monthly temperature is the average of the mean daily temperatures of the month. The mean annual temperature similarly is the average of the mean monthly temperatures.

Mean monthly temperatures are available for periods of years for Allentown, Coopersburg, and North Whitehall and Egypt.

Maximum Temperature

Records of maximum temperatures at Allentown are available since November, 1922, enough to afford a fairly accurate picture of average conditions. An examination of the tables below will show that the highest temperature recorded at Allentown was 103° F. in July, 1936. The highest temperatures are experienced in July most commonly, although in certain years the hottest days have been in August or June, occasionally in September and May. In 1915 the highest temperature of the year in many places in eastern Pennsylvania was registered on April 25.

Minimum Temperature

Minimum temperatures for Allentown are available for a number of years. As far as recorded by the observers working in cooperation with the U. S. Weather Bureau, the lowest temperature for Allentown was—12° F. in February 1934. No doubt Allentown experienced a lower temperature in January 1912, which was an extremely cold month in the Lehigh Valley, but at that time no official observerations were made.

Temperatures in the following tables are degrees Fahrenheit:

Monthly and annual mean temperatures at North Whitehall and Egypt

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1856	19.9	23.2	28.7	49.5	56.5	67.4	74.8	68.9	64.0	50.1	41.4	29.4	47.8
1857	18.3	35.2	34.7	41.4	57.3	65.4	72.9	70.9	62.7	52.7	41.3	36.4	49.1
1858	35.5	25.8	37.4	49.3	56.4	72.8	75.5	70.7	62.9	56.1	38.2	32.4	51.1
1859	29.9	32.6	43.9	47.3	62.8	66.4	71.5	70.3	61.7	48.8	42.6	28.1	50.5
1860	24.4	27.6	40.3	45.4	61.2	67.4	72.0	71.7	61.7	54.7	44.0	29.1	50.4
1861	27.9	33.3	38.3	49.6	53.4	68.9	71.6	71.4	64.5	66.8	40.6	34.8	51.1
1862	29.8	28.9	35.1	46.7	60.0	64.4	71.5	71.5	66.3	53.6	40.1	32.8	50.1
1863	32.0	30.2	30.8	47.0	62.3	63.1	73.3	73.8	60.0	51.9	43.0	31.3	50.2
1864	28.6	31.8	36.6	48.4	66.6	66.6	73.2	74.6	61.1	50.5	41.6	31.9	51.9
1865	21.7	28.2	43.3	53.0	60.8	72.6	71.7	69.6	68.1	49.6	41.3	32.7	51.1
1866	25.6	29.5	35.2	51.8	55.3	67.8	75.2	65.2	64.1	63.1	41.9	28.5	48.5
1867	21.2	34.7	34.6	49.7	54.4	67.6	71.5	70.5	63.2	52.1	42.4	27.3	49.1
1868	24.4	21.5	36.5	43.5	57.1	67.8	77.5	72.7	63.4	48.2	42.0	27.9	48.5
1869	32.1	32.3	34.1	49.2	57.8	68.2	71.7	71.0	64.5	48.5	37.2	32.9	50.0
1870	34.7	30.4	33.3	51.4	63.3	74.0	78.1	74.1	67.1	54.5	46.5	31.5	52.8
1871	27.7	29.8	42.6	52.1	61.7	69.1	71.6	74.5	60.1	52.5	37.6	27.1	50.6
1872	27.4	—	30.6	50.0	63.6	71.6	77.0	75.6	65.9	50.4	37.8	—	—
1873	24.8	26.9	33.1	45.8	58.4	69.9	75.3	71.0	64.0	61.2	34.3	33.3	49.0
1874	—	30.5	37.1	40.2	59.6	71.5	73.5	69.5	67.2	52.2	39.1	30.1	—
1875	22.1	19.4	30.1	42.4	61.7	69.8	74.1	71.8	62.8	50.2	36.6	31.5	47.7
1876	32.9	31.6	34.2	44.0	60.9	73.5	77.5	—	—	48.9	43.2	22.2	—
1877	24.6	33.8	34.1	50.1	60.8	72.2	75.9	—	66.3	56.2	44.0	39.0	—
1878	30.6	34.6	45.9	57.2	60.5	67.9	76.7	73.6	67.1	55.8	42.7	31.7	53.7
1879	24.0	26.2	38.6	48.4	63.9	71.3	75.9	71.7	63.0	60.6	42.1	35.0	51.7
1880	37.4	30.9	37.7	51.3	70.1	74.2	74.9	75.2	67.7	64.0	37.4	27.2	53.5
1881	24.7	29.1	38.4	48.7	—	—	—	—	—	—	—	—	—
Average	27.5	29.7	36.5	48.5	60.2	71.0	75.0	72.2	64.8	52.8	39.9	30.6	50.8

Monthly and annual mean temperatures at Coopersburg

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1890	37.8	37.2	34.9	50.0	59.8	70.0	70.4	68.8	62.9	53.3	41.7	28.2	51.2
1891	32.1	35.5	35.0	51.7	58.5	69.3	68.1	69.9	66.5	50.6	39.7	39.8	51.4
1892	27.0	32.5	32.7	48.2	59.3	70.8	73.0	71.3	62.4	51.5	39.8	—	—
1893	20.2	27.8	34.8	47.7	58.7	68.3	72.0	71.5	60.4	53.2	39.8	32.2	48.9
1894	34.0	28.6	43.8	49.4	60.8	69.9	74.8	70.5	66.8	54.3	39.4	34.1	52.2
1895	27.0	24.0	35.4	49.4	60.7	71.2	70.0	74.3	68.4	48.6	44.8	36.8	50.9
1896	30.6	32.4	34.5	53.8	65.5	67.6	74.3	73.0	66.0	52.2	49.1	34.2	52.8
1897	29.8	34.5	41.4	50.8	59.8	65.3	73.8	70.4	66.4	56.4	44.8	37.4	52.6
1898	34.4	35.0	47.8	47.8	59.5	72.8	77.2	74.3	69.0	57.2	43.8	33.6	54.4
1899	29.4	27.1	39.2	50.4	60.6	71.3	73.2	71.6	63.2	55.8	45.0	36.4	51.9
1900	32.6	31.0	35.4	51.6	60.4	71.0	75.6	74.8	68.6	60.0	47.2	34.2	53.5
Average	30.4	31.4	37.7	50.1	60.3	69.8	72.9	71.9	65.5	53.9	43.2	35.1	51.8

Monthly and annual mean temperatures at Allentown

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1922	—	—	40.6	51.4	64.8	72.0	73.5	—	—	—	43.3	31.2	—
1923	27.5	24.4	35.2	49.0	59.7	74.2	73.8	71.4	66.1	51.8	40.6	—	—
1924	—	27.2	37.8	47.6	56.8	67.4	73.1	72.2	62.2	54.4	40.6	30.2	—
1925	23.6	34.4	41.0	50.0	57.4	74.8	72.1	71.4	67.5	47.4	40.5	32.4	51.0
1926	28.6	28.3	33.6	46.6	60.6	65.6	74.0	72.8	63.8	—	40.8	26.8	—
1927	27.8	34.4	41.8	48.2	57.8	65.4	73.4	66.8	65.4	56.5	45.5	34.4	51.4
1928	31.9	30.1	36.9	47.0	58.9	66.2	74.8	73.8	61.2	54.4	43.8	35.1	51.2
1929	28.4	29.2	43.6	51.0	59.8	69.9	73.6	69.8	66.8	50.7	42.6	30.5	51.3
1930	27.8	32.6	38.5	47.2	61.9	71.0	74.0	71.2	68.1	50.8	41.2	30.6	51.2
1931	29.3	30.9	37.6	49.1	59.8	68.3	75.6	72.0	69.4	56.4	48.9	37.6	52.9
1932	40.6	33.6	34.4	46.8	59.6	68.2	72.5	72.4	65.4	54.2	38.9	32.8	51.6
1933	35.6	29.3	36.3	50.0	62.0	70.2	72.9	71.4	66.0	51.4	37.6	30.0	51.0
1934	30.3	16.4	33.6	48.2	61.3	71.8	74.8	68.4	65.4	51.2	45.0	31.2	49.8
1935	25.3	27.6	40.4	48.6	57.5	69.4	75.8	71.6	61.4	55.0	46.8	28.2	50.6
1936	24.5	21.6	44.0	46.9	63.8	70.0	75.8	74.6	66.6	54.4	39.8	35.8	51.5
1937	36.2	32.8	35.6	48.8	63.2	71.6	74.8	75.4	63.8	52.4	43.2	32.0	52.5
1938	29.3	32.8	42.2	52.2	59.6	68.9	74.4	75.2	62.6	55.6	44.6	33.4	52.6
1939	29.8	33.4	35.6	45.6	63.8	70.9	73.9	75.4	66.2	53.0	39.9	33.1	51.6
1940	22.3	30.6	32.8	45.4	59.6	68.0	74.2	69.3	62.6	49.2	41.8	35.2	49.2
Average	29.3	29.4	38.0	48.4	60.4	69.7	74.1	72.0	65.0	52.8	42.4	32.3	51.1

Average monthly and annual mean temperatures for Lehigh County (North Whitehall and Egypt 1856-1881, Coopersburg 1890-1900, Allentown 1922-1940)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
° F.	28.6	30.3	33.7	48.6	60.3	69.5	73.9	71.8	64.7	53.7	41.8	32.1	51.0

Maximum temperature at Allentown

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1922	—	—	—	—	—	—	—	—	—	—	64	55
1923	50	43	73	87	86	100	98	92	88	72	61	62
1924	—	—	68	76	87	91	94	100	95	82	73	63
1925	45	62	74	86	95	100	96	93	90	74	65	56
1926	57	50	69	79	86	88	101	95	90	86	70	46
1927	45	56	77	88	82	95	97	84	95	92	74	61
1928	58	53	75	82	90	90	94	95	88	86	76	60
1929	62	56	75	90	94	95	96	96	96	74	75	58
1930	65	74	72	73	94	93	101	98	91	79	66	48
1931	54	54	58	75	91	97	97	95	95	84	73	63
1932	71	59	59	77	90	90	92	94	97	80	60	64
1933	56	57	59	81	86	98	99	97	87	80	69	53
1934	54	49	67	75	92	99	95	88	84	72	74	65
1935	52	54	76	87	89	92	95	94	84	83	75	55
1936	44	47	74	84	93	95	103	96	90	78	76	61
1937	66	59	61	81	92	95	97	95	94	78	67	58
1938	60	63	82	89	83	94	93	95	86	88	74	57
1939	53	63	76	84	92	94	94	93	97	89	70	60
1940	55	58	63	73	89	91	98	91	87	78	72	60
Average	55.7	56.3	69.9	81.5	89.5	94.3	96.7	93.9	90.8	80.8	70.2	58.2
Highest	71	74	82	90	95	100	103	100	97	92	76	65

Minimum temperature at Allentown

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1922	—	—	—	—	—	—	—	—	36	28	25	13
1923	5	7	11	12	34	51	55	47	38	30	23	19
1924	—	7	18	25	35	43	52	49	40	30	11	10
1925	-6	10	8	28	30	48	51	49	38	22	23	9
1926	2	10	12	25	33	43	51	53	45	31	21	3
1927	0	19	20	28	35	43	51	42	40	36	26	15
1928	-5	6	18	28	37	45	53	52	36	27	22	14
1929	6	5	12	32	35	41	47	50	40	30	10	10
1930	-1	3	16	21	40	42	51	45	44	26	11	9
1931	12	10	23	29	30	47	57	54	39	32	25	18
1932	23	14	10	27	40	39	52	52	34	30	12	3
1933	13	-3	15	28	39	40	46	51	42	25	12	-2
1934	1	-12	-5	29	35	52	53	41	43	30	23	12
1935	-7	-6	14	29	35	50	57	48	38	30	24	8
1936	-5	-2	14	27	35	47	51	51	36	21	18	9
1937	19	13	18	29	36	50	55	54	38	25	25	11
1938	1	10	8	25	35	40	50	53	40	32	3	16
1939	-1	10	17	28	36	46	49	54	39	29	22	10
1940	-1	13	14	24	38	43	49	42	34	22	20	9
Average	3.4	6.3	13.5	26.3	35.4	45.0	51.7	49.3	38.9	28.2	18.7	10.3
Lowest	-7	-12	-5	12	30	39	46	41	34	21	3	-2

Dates of highest and lowest temperatures at Allentown

Year	Highest	Lowest
1922		
1923	100 June 20	5 January 30
1924	100 August 6	
1925	100 June 6	-6 January 28
1926	101 July 22	2 January 29
1927	97 July 13	0 January 27
1928	95 August 4	-5 January 30
1929	96 July 28, Aug. 1, Sept. 3	5 February 23
1930	101 July 21	-1 January 20
1931	97 June 20, July 1	10 February 1, 3
1932	97 September 1	3 December 19
1933	99 July 31	-3 February 13
1934	99 June 29	-12 February 9
1935	95 July 12	-7 January 28
1936	103 July 9	-5 January 23, 24
1937	97 July 8	11 December 11
1938	95 August 18	1 January 19
1939	97 September 8	-1 January 20
1940		

Killing Frost

Closely connected with the temperatures discussed above are the first killing frost in the autumn and the last one in the spring, as they determine the harvesting and planting times. Naturally, there will be difference of opinion as to the exact dates owing to the fact that some plants are killed by temperatures that scarcely affect others, and that vegetation in the lowlands may be killed on a cold night without material injury to equally susceptible plants growing on uplands.

It should also be recognized that killing frosts may occur without the official thermometers registering freezing temperature, for they always are placed in shelters some feet above the ground or on the tops of buildings. The ground temperature may be and usually is several degrees lower than that recorded in the instrument shelters.

Generalizing for the Lehigh Valley it may be said that the average date of the first killing frost in the autumn is about October 16 or 17, although it may occur in the latter part of September or as late as the first week in November. The average date of the last killing frost in the spring is about April 18, although it may be March 18 or as late as the middle of May. Light frost has been reported in favorable places during June and also in August. The average growing season for the section is, therefore, almost exactly six months or half of the year.

Sometimes the fruit crop of a season, particularly the peach crop, is ruined by freezing. This is rarely due entirely to the extremely low temperature of the winter. Practically all the fruit grown in the region can withstand lower temperatures than are experienced here provided the buds are still dormant. Occasionally during January, February, or early March several days of unduly warm weather start growth and cause the buds to swell so much that they lose their winter protection and are killed when normal weather returns. Some of the spring-flowering shrubs, such as forsythia, may burst into bloom during periods of unusually warm weather in mid-winter. Cherry trees also have been known to bloom under these conditions. Fruit trees on the south slopes of hills are more liable to damage since they become heated more than trees less directly exposed to the sun's rays.

Precipitation

Ranking with temperature in importance is precipitation, including both rain and snow. Frost, dew, and fog are of some effect, but they are not measurable. Dew is especially heavy during the summer months and materially contributes to the moisture required by growing plants. It, therefore, should not be ignored. Following a clear night, the grain, grass and weeds are so wet that one cannot walk through them in the morning without becoming thoroughly drenched.

The tables for precipitation include both rain and snow, as the common practice is to melt the snow and measure the resulting water. Reliable figures of precipitation extending over considerable periods are available for Allentown, Coopersburg, and North Whitehall and Egypt. These are presented in the following pages and show well the variations in precipitation that occur. Attention is directed to a few of these. The average annual precipitation is about 43 inches, but it has ranged from 29.65 at Allentown in 1930 to 57.58 at Coopersburg in 1890. The rainfall is fairly well distributed throughout the year. The average rainfall during July and August is in excess of four inches. June averages almost as high. The other months average somewhat more than three inches. The greatest monthly rainfall on record was 14.78 inches at Coopersburg in May 1894. All of the months except February, March, May, and July have at some time or place had less than one inch of rainfall. One inch has been recorded as the minimum for March and May, 1.05 for February, and 1.14 for July.

Precipitation at North Whitehall and Egypt, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1874	—	3.00	1.50	4.95	2.05	3.70	2.85	3.35	3.00	4.08	2.15	2.57	—
1875	1.80	1.70	4.45	1.35	1.00	2.07	1.15	8.55	1.90	4.35	—	1.95	—
1876	0.70	3.88	4.80	0.40	2.45	2.00	3.60	1.20	6.60	1.35	4.50	1.50	32.98
1877	1.85	1.35	5.60	2.70	1.40	5.70	5.60	2.60	3.50	6.05	6.80	1.25	44.40
1878	5.25	2.20	3.70	3.39	4.53	2.62	5.47	2.50	6.05	3.00	2.10	3.60	44.41
1879	2.50	1.95	3.35	3.29	1.80	7.25	1.90	5.75	2.50	1.10	1.60	6.10	39.09
1880	4.45	3.85	2.00	3.00	1.70	5.20	4.85	1.15	1.87	1.90	3.55	1.25	34.77
1881	2.90	4.12	5.05	—	—	—	—	—	—	—	—	—	—
Average	2.88	2.79	3.52	2.26	2.47	3.67	3.89	4.21	3.52	3.44	3.45	2.82	38.92

Precipitation at Coopersburg, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1890	2.88	5.32	7.92	3.21	7.93	3.14	5.53	6.72	4.18	6.04	0.95	3.76	57.58
1891	7.29	4.57	6.54	2.50	2.25	2.33	6.07	7.16	2.04	2.74	2.27	4.83	50.59
1892	6.98	1.05	4.77	1.58	5.12	4.42	3.48	4.05	3.56	0.60	6.78	1.78	44.17
1893	4.26	6.50	2.53	4.07	5.42	2.86	1.96	6.22	3.23	3.26	3.89	2.64	46.84
1894	1.69	4.26	1.60	3.18	14.78	2.58	2.65	2.43	5.86	5.62	2.75	5.04	52.44
1895	4.19	1.71	2.60	5.40	3.08	2.40	4.00	3.29	0.75	4.08	2.32	3.22	37.04
1896	1.13	6.88	5.43	1.35	4.15	3.45	8.46	0.66	6.08	3.29	4.87	1.04	46.79
1897	2.62	3.73	2.77	3.59	8.74	4.33	6.48	2.92	2.07	2.65	6.80	4.76	51.46
1898	4.41	3.82	2.55	3.98	7.05	1.04	2.70	5.03	0.91	6.05	7.22	3.78	48.54
1899	4.73	5.15	6.82	1.85	3.14	3.17	4.53	4.88	7.25	1.48	2.20	1.69	46.89
1900	3.31	5.48	3.70	1.94	2.72	1.35	6.76	2.33	1.86	2.20	2.12	2.59	36.36
Average	3.95	4.41	4.29	2.97	5.85	2.82	4.78	4.15	3.44	3.46	3.83	3.11	47.06

Precipitation at Allentown, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1912	3.25	2.48	5.85	3.37	4.32	2.71	2.85	5.10	7.43	3.31	3.17	3.59	47.43
1913	3.94	2.09	7.24	6.82	2.60	2.00	3.64	4.10	3.97	5.80	2.79	4.07	49.06
1914	3.93	4.53	2.03	3.74	2.96	2.48	5.20	2.92	0.28	1.61	2.01	5.53	37.25
1915	6.03	5.74	1.00	2.70	3.76	2.15	4.34	11.19	3.65	4.02	2.07	4.82	51.47
1916	1.94	3.09	4.01	3.31	2.20	4.71	9.88	0.81	3.58	1.82	2.30	3.96	41.61
1917	3.70	1.45	4.54	1.90	2.27	5.47	5.27	4.08	2.88	5.87	0.65	2.58	40.66
1918	5.15	2.36	2.04	4.89	3.96	3.04	2.57	4.20	2.91	1.02	1.65	3.75	37.54
1919	2.50	2.05	5.13	2.34	8.07	4.76	7.61	2.67	2.29	5.60	3.10	1.98	48.10
1920	2.45	3.59	—	5.51	2.48	3.61	4.05	4.07	3.16	1.65	3.87	4.38	—
1921	2.55	4.22	2.37	3.10	3.82	1.63	5.67	4.42	4.30	1.78	5.12	2.24	41.22
1922	—	—	4.60	3.23	4.33	4.57	4.08	4.24	1.87	1.47	0.47	2.13	—
1923	5.11	2.34	3.68	3.14	3.01	0.61	2.46	2.40	3.63	4.57	2.11	5.35	38.49
1924	5.14	4.26	1.46	4.79	5.07	4.85	3.80	3.73	5.00	1.66	2.50	2.12	44.38
1925	5.80	2.08	2.75	1.62	3.56	2.50	5.98	4.54	4.12	5.64	3.17	2.32	44.08
1926	2.29	4.54	1.81	2.26	2.31	3.41	7.04	5.85	4.23	4.48	5.46	2.75	46.43
1927	2.56	3.03	1.44	3.18	3.55	5.53	3.04	7.49	1.64	6.84	3.88	6.54	48.72
1928	2.61	4.19	2.76	5.34	2.50	5.49	6.68	9.95	2.22	0.62	1.54	1.42	45.32
1929	3.39	3.25	2.54	7.31	2.66	3.29	1.83	4.10	5.09	4.67	3.19	2.86	44.18
1930	2.24	2.36	2.27	2.86	3.85	2.65	4.74	1.71	1.45	0.97	1.76	2.79	29.65
1931	2.04	2.15	2.99	1.79	3.01	5.81	8.92	3.00	1.65	2.44	0.43	2.11	36.34
1932	3.42	1.57	4.53	2.22	4.73	2.30	2.09	3.17	0.95	5.40	7.05	2.21	39.64
1933	1.73	3.16	4.96	4.71	6.11	2.51	5.61	11.00	5.94	1.96	0.72	1.82	50.23
1934	2.69	1.48	2.60	4.08	4.57	5.00	3.97	4.17	10.19	1.82	3.05	3.60	47.22
1935	2.63	2.20	2.63	2.70	1.04	4.55	7.91	4.15	5.13	3.50	5.62	1.61	43.67
1936	6.48	2.80	5.97	3.04	2.87	6.10	1.14	3.96	0.87	3.84	1.47	5.31	43.85
1937	5.47	2.41	2.36	4.10	2.81	3.65	5.46	6.58	0.91	3.73	2.02	1.61	41.11
1938	3.01	2.22	2.13	3.14	2.98	10.51	8.99	2.25	7.22	3.04	2.98	2.67	51.14
1939	3.02	4.30	4.82	4.05	1.73	2.51	3.59	2.62	1.33	3.00	1.38	2.51	34.86
1940	1.32	2.56	5.59	5.44	4.57	2.73	6.33	2.96	4.01	2.00	4.75	3.73	47.99
Average	3.44	2.94	3.43	3.67	3.51	3.83	4.99	4.53	3.51	3.25	2.76	3.18	42.74

Maximum and minimum precipitation by months and year of occurrence for Lehigh County (45 or 46 years)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Maximum:													
Inches	7.29	6.88	7.92	7.31	14.78	10.51	9.88	11.19	10.19	6.84	7.22	6.54	51.47
Year	1891	1896	1890	1929	1894	1938	1916	1915	1934	1927	1932	1927	1915
Minimum:													
Inches	0.70	1.05	1.00	0.40	1.00	0.61	1.14	0.66	0.28	0.60	0.43	1.04	29.65
Year	1876	1892	1915	1876	1875	1923	1936	1896	1914	1892	1931	1896	1930

Average monthly and annual precipitation for Lehigh County (North Whitehall and Egypt 1874-1881, Coopersburg 1890-1900, Allentown 1912-1940)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Inches	3.46	3.20	3.69	3.37	3.80	3.63	4.74	4.30	3.51	3.27	3.11	3.10	43.86

Records of unusually heavy precipitation

Allentown

Inches		
4.88	about 35 hours	Sept. 29-30, 1924
4.77	24 hours ending 8 a. m.	Aug. 24, 1933
4.05	about 25 hours	Sept. 7-8, 1934
5.67	48 hours ending 8 a. m.	July 8-9, 1935
3.63		June 18, 1938
4.26		June 26-28, 1938
6.33		July 20-24, 1938
5.80		Sept. 20-22, 1938

Coopersburg

7.12		May 20-21, 1894
3.88		May 28, 1894
3.47	during the night	Feb. 5-6, 1896
3.58		May 12-13, 1897
3.50		Nov. 1-2, 1897
1.30	30 minutes	Aug. 10, 1899
3.10	during night	Aug. 26-27, 1899

Snowfall

The snowfall records (as melted snow) have been included in the precipitation data, but it is well to discuss the snowfall of the region separately as depth of snow on the ground. The data on snow are less abundant and less accurate than those of rain. The principal reason for this is that the snow is apt to fall with wind that sweeps it from some places and piles it up in others. The proportion of water to depth of snow also is variable. The Weather Bureau considers that a fair average is 10 inches of snow to 1 inch of water. The range is from 2 to 1 in unusually dense snow to 63 to 1 in the most fluffy snow on record.

The older residents generally believe that in their youth the winter snowfalls were much heavier than in recent years. The records of different places in eastern Pennsylvania show that the winters averaged somewhat colder and wetter between 1850 and 1870, but data on snowfall are lacking. Certainly it is true that heavy snow storms before the advent of hard roads, automobiles, and State highway supervision resulted in much more inconvenience than now. Sleighs formerly used for weeks at a time in this region have now practically disappeared.

The farmers look with favor on falls of snow that cover the ground and form a protection to winter wheat and other grains. On the other hand, some of the most disastrous floods have resulted from sudden melting of deep accumulations of snow by unseasonably warm periods or by heavy rains.

Snowfall varies greatly in amount and time of occurrence. The greatest fall occurs in December, January, and February, although occasional heavy falls occur during November and March. In most sections of eastern Pennsylvania the heaviest single snow on record fell March 10-12, 1888, when a depth between twenty and thirty inches was measured in some places. This is commonly known as the ''Great Blizzard.'' It affected a large portion of the Atlantic seaboard. Snow occasionally covers the ground for a short time even during April and October, and snow flurries occur during May and September. A very late snow in the spring is commonly termed the ''onion snow.''

The average annual snowfall at Allentown for 15 years given in the following table is evidently too low, as it includes some years of abnormally light snows. A fairer average would be near 30 inches. Philadelphia over a period of 58 years has an average of 24.3 inches. The average seasonal snowfall for Reading, also with a long record, is 29.5 inches. As it is a common occurrence in winter that a storm passing through eastern Pennsylvania yields rain in Philadelphia and snow in the Lehigh Valley, the snowfall for this region over a longer term of years should be considerably higher than Philadelphia and probably slightly higher than Reading.

Snowfall (unmelted) at Allentown, in inches

Year	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Annual
1923	12.0	*	*	0	trace	2.5	
1924	*	12.2	*	12.0	trace	0.2	
1925	43.2	*	trace	0	1.7	0.7	**
1926	3.9	25.0	0.4	trace	trace	6.6	35.9
1927	5.1	10.1	0	0	trace	2.0	17.2
1928	12.0	4.6	11.0	trace	trace	0.3	27.9
1929	2.2	8.2	3.2	trace	trace	8.5	22.1
1930	9.8	3.0	0.5	0	trace	3.5	16.8
1931	1.5	3.6	2.4	0	1.5	trace	9.0
1932	trace	1.3	2.2	trace	trace	9.4	12.9
1933	1.4	9.6	2.0	trace	2.2	9.9	25.1
1934	trace	17.6	7.3	trace	trace	0.2	25.1
1935	10.8	9.4	3.0	0.2	1.6	8.2	33.2
1936	15.4	18.8	2.0	trace	1.5	3.0	40.7
1937	4.1	3.8	10.7	trace	0.1	1.5	20.2
1938	4.8	0.2	1.3	1.3	15.0	0.8	23.4
1939	11.0	2.5	5.5	trace	trace	1.6	20.6
1940***	4.9	14.7	2.1	3	2.3	2.5	30.0
Average							24.0

* Record lacking.

** 2.2 inches in October.

*** 0.5 inch in October.

Humidity

Humidity data for stations in Lehigh County are not available, so it has seemed advisable to include here the discussion on this subject published in the volume on Northampton County of this Survey.

In recent years considerable attention has been given to the relative humidity of the atmosphere. High humidity in hot weather produces an oppressive feeling and results in numerous sunstrokes or heat strokes because of slow evaporation of the body perspiration. In cold weather high humidity increases the rate of conduction of heat from the body and produces chilliness. The east wind of an approaching storm always feels much colder in the winter because of the increase in the relative humidity.

Continuous relative humidity charts from a recording hair hygrometer for the past thirteen years are on file in Lehigh University. These show great variations ranging from 15 to 100 percent. Except when precipitation is actually taking place, the relative humidity seldom rises higher than 85 percent. It also rarely measures less than 15 percent. In addition to the recording instrument data, each day at 4:00 P. M. Eastern Standard Time, the relative humidity is obtained by means of a whirled psychrometer. The averages of relative humidity for each month determined in this way, of the years 1928 to 1937 inclusive, are given in the following table.

Relative humidity monthly averages determined at Lehigh University daily at 4:00 P. M. (Eastern Standard Time) from 1928 to 1937, inclusive.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1928	—	—	—	47.0	42.3	58.3	56.2	62.4	54.2	53.9	61.4	58.3	55.2
1929	59.6	58.3	50.1	54.3	48.6	43.9	43.7	46.8	56.6	53.7	60.3	65.0	53.7
1930	65.1	68.4	50.3	46.8	45.3	46.6	49.8	42.7	44.9	43.2	57.4	62.8	52.4
1931	55.0	53.4	56.0	43.0	49.1	45.3	48.7	53.2	55.1	49.9	58.5	55.2	51.8
1932	63.0	51.7	51.3	38.6	40.0	50.4	39.1	40.5	37.2	51.5	54.7	63.6	48.4
1933	57.9	53.3	59.2	52.3	61.7	51.6	54.4	60.3	57.6	51.4	59.7	63.2	56.8
1934	61.1	50.4	55.2	49.8	52.3	55.2	53.7	56.7	67.7	49.2	58.4	54.7	55.5
1935	62.3	55.5	52.5	48.5	39.5	49.8	54.2	51.3	52.8	48.1	69.8	65.4	54.1
1936	67.8	60.0	63.0	54.3	44.0	51.2	40.9	46.4	53.7	51.4	50.9	58.6	53.6
1937	64.4	47.3	48.3	47.2	49.8	62.7	54.8	63.8	57.8	48.5	47.6	49.4	53.5
Average	61.8	55.4	54.0	48.2	47.3	51.5	49.6	52.4	54.8	50.1	57.9	59.6	53.5

It should be remembered that in general the relative humidity is lowest at the time of day of highest temperatures and vice versa. Therefore, the 4:00 P. M. figures are nearly the lowest of the day.

General Character of Weather

The meteorological observers in the Lehigh Valley have usually recorded the general character of each day as clear, cloudy, or partly cloudy and have also noted the days in which .01 inch of precipitation has occurred. At Lehigh University since December 1925 there has been in operation a sunshine recorder such as is used at the principal stations of the U. S. Weather Bureau and since that time the record for sunshine is almost complete. These record sheets are preserved at the university.

Character of weather in Allentown

Year	Number of days				Prevailing wind direction
	Precipitation .01 in. or more	Clear	Partly cloudy	Cloudy	
1923	129				West
1924	124				West
1925	121	158	170	37	Northwest
1926	142	181	136	48	Northwest
1927	137	209	113	43	South
1928	118	175	140	51	Southwest
1929	125	199	113	53	Northeast
1930	104	221	88	56	Southwest
1931	120	215	70	80	Northeast
1932	117	202	68	96	Northeast
1933	141	219	59	87	Southwest
1934	119	226	52	87	Northeast
1935	135	202	60	103	Northeast
1936	138	194	104	68	Northeast
1937	141	176	153	36	Northeast
1938	138	198	136	31	Northeast
1939	109	196	147	22	Northeast
1940	127	173	141	51	South

Winds

The winds of the Lehigh Valley are generally light. The usual wind velocity is about five to seven miles an hour except during storms. Occasionally periods of calm prevail for many hours at a time. The greatest wind velocity recorded at the Lehigh University station, Bethlehem, since the establishment of the automatic recording instruments in 1925 was 45 miles per hour on December 20, 1934. Because this instrument makes a record only on the completion of each mile of wind blown, it is certain that occasional gusts have much higher velocity. It is estimated that the maximum is perhaps 60 miles per hour.

The wind normally blows from the west, southwest or northwest, inasmuch as the region lies within the Prevailing Westerlies wind belt of the globe. During the summer months the direction is predominantly from the southwest and during the winter almost equally from the northwest and southwest. Whirling storm areas entering the region bring easterly winds as explained below. In some months northeastern winds are more common than the westerly ones. The wind changes direction with the approach and passing of the storm.

The major storms almost invariably come from the west and pass to the northeast.

For several years past the meteorological station of the Allentown-Bethlehem Airport has been collecting wind data. The location of the station is extremely favorable for accurate records of surface wind direction and velocity in that the region is level and with no nearby high buildings or trees. The tables that follow are presented as the most reliable wind data that have thus far been assembled for the region. It will be observed that the four cardinal directions and the directions half-way between are represented by far more occurrences than those intermediate ones such as NNE, ENE, ESE, etc. The observer in charge of the station attributes this condition to the fact that steady winds usually come from the eight major directions. The intermediate directions are usually noted only at times of light shifting and variable winds. The following tables show the number of times winds in each direction have been observed.

Direction and velocity of winds at Allentown-Bethlehem Airport
January 1930-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4–15	355	90	649	70	253	18	63	14	206	70	1063	151	515	102	586	78	4283	64
16–31	24	16	48	20	9	5	6	1	8	7	78	42	262	88	327	24	965	14
32–47			2					1		4		2	10	4	18		41	1
Over 47																		
Calm																	1402	21
Total obs.	379	106	699	90	262	23	69	16	214	81	1141	195	787	194	931	102	6691	
%	6	2	10	1	4	‡	1	‡	3	1	17	3	12	3	14	2	Calm 21	100

February 1929-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4–15	344	122	627	80	203	19	111	22	188	78	959	126	397	102	661	143	4182	62
16–31	45	23	82	4	7	1	9		1	1	58	46	242	98	524	59	1200	17
32–47			2				1					1	3	7	25	2	41	1
Over 47													1				1	‡
Calm																	1339	20
Total obs.	389	145	711	84	210	20	121	22	189	79	1017	173	643	207	1210	204	6763	
%	6	2	10	1	3	‡	2	‡	3	1	15	3	10	3	18	3	Calm 20	100

Direction and velocity of winds at Allentown-Bethlehem Airport

March 1929-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total observations	%
4–15	294	166	607	108	239	45	133	24	266	148	953	147	380	115	659	96	4380	59
16–31	67	28	118	44	41	14	19	5	43	23	123	68	293	186	613	87	1772	24
32–47	3		7	8	3		1	2		1	3	2	41	24	57	3	155	2
Over 47													4				4	‡
Calm																	1116	15
Total obs.	364	194	732	160	283	59	153	31	309	172	1079	217	718	325	1329	186	7427	
%	5	3	10	2	4	1	2	‡	4	2	14	3	10	4	18	3	Calm 15	100

April 1929-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total observations	%
4–15	228	84	600	110	356	59	271	42	296	157	755	102	301	112	552	117	4142	58
16–31	50	19	159	50	84	14	43	11	57	23	109	80	293	127	364	73	1556	22
32–47	1	1	21	3			4					1	18	9	8	2	68	1
Over 47																		
Calm																	1354	19
Total obs.	279	104	780	163	440	73	318	53	353	180	864	183	612	248	924	192	7120	
%	4	1	11	2	6	1	4	1	5	3	12	3	9	3	13	3	Calm 19	100

May 1929-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total observations	%
4–15	371	106	367	137	360	88	217	57	458	251	1215	154	330	114	492	146	4863	66
16–31	51	1	31	5	41	4	13	7	47	29	72	35	95	66	184	90	771	10
32–47											1		9	1		1	12	‡
Over 47																		
Calm																	1779	24
Total obs.	422	107	398	142	401	92	230	64	505	280	1288	189	434	181	676	237	7425	
%	6	2	5	2	5	1	3	1	7	4	17	3	6	2	9	3	Calm 24	100

Direction and velocity of winds at Allentown-Bethlehem Airport
June 1929-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4–15	359	91	425	110	234	83	268	75	433	276	1074	166	309	94	499	115	4611	64
16–31	27	3	27	8	6	9	21	5	35	31	74	20	32	38	150	40	526	8
32–47													1		5		6	‡
Over 47																		
Calm																	2038	28
Total obs.	386	94	452	118	240	92	289	80	468	307	1148	186	342	132	654	155	7181	
%	6	1	6	2	3	1	4	1	7	4	16	3	5	2	9	2	Calm 28	100

July 1930-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4–15	218	81	362	67	227	56	196	50	490	273	997	252	371	85	398	121	4244	63
16–31	8	8	16	1	8	2	6	4	14	17	33	17	51	27	91	23	326	5
32–47	1													1	1		3	‡
Over 47											1						1	‡
Calm																	2122	32
Total obs.	227	89	378	68	235	58	202	54	504	290	1031	269	422	113	490	144	6696	
%	3	1	6	1	4	1	3	1	8	4	15	4	6	2	7	2	Calm 32	100

August 1929-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4–15	370	173	621	128	231	52	227	96	455	203	1021	167	389	76	491	146	4846	65
16–31	11	3	44	10	4	2	6	3	17	8	25	4	23	18	56	23	257	4
32–47	1		2		3										3		9	‡
Over 47																		
Calm																	2321	31
Total obs.	382	176	667	138	238	54	233	99	472	211	1046	171	412	94	550	169	7433	
%	5	3	9	2	3	1	3	1	6	3	14	2	6	1	8	2	Calm 31	100

Direction and velocity of winds at Allentown-Bethlehem Airport
September 1930-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4-15	409	147	628	138	228	68	169	68	371	159	906	211	382	96	430	146	4556	70
16-31	45	16	59	5	2	1	1	1	4	11	21	14	56	20	74	23	353	6
32-47															3		3	‡
Over 47																		
Calm																	1568	24
Total obs.	454	163	687	143	230	69	170	69	375	170	927	225	438	116	507	169	6480	
%	7	2	11	2	3	1	3	1	6	3	14	3	7	2	8	3	Calm 24	100

October 1930-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4-15	441	103	481	98	219	52	135	52	301	131	993	208	505	123	461	184	4487	67
16-31	36	10	50	14	15	4	35	12	34	7	54	22	97	71	132	48	641	10
32-47													1		12	1	14	‡
Over 47																		
Calm																	1553	23
Total obs.	477	113	531	112	234	56	170	64	335	138	1047	230	603	194	605	233	6695	
%	7	2	8	2	3	1	3	1	5	2	16	3	9	3	9	3	Calm 23	100

November 1930-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total obser-vations	%
4-15	262	153	538	120	219	49	96	54	294	144	995	236	541	119	392	100	4312	67
16-31	69	26	48	9	17	2	4	13	25	8	65	43	155	75	188	64	811	13
32-47	3		1	2	1								5	4	5	6	27	‡
Over 47													1				1	‡
Calm																	1327	20
Total obs.	334	179	587	131	237	51	100	67	319	152	1060	279	702	198	585	170	6478	
%	5	3	9	2	4	1	2	1	5	2	16	4	11	3	9	3	Calm 20	100

Direction and velocity of winds at Allentown-Bethlehem airport 1930-1938
December 1930-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total observations	%
4–15__	368	113	687	83	158	11	66	13	166	61	1090	184	495	111	605	101	4312	65
16–31__	30	9	48	2	12	3	3		10	5	111	54	220	100	373	28	1008	15
32–47__	1					1	1					3	8	8	5		27	‡
Over 47___																		
Calm_																	1346	20
Total obs.	399	122	735	85	170	15	70	13	176	66	1201	241	723	219	983	129	6693	
%_____	6	2	11	1	2	‡	1	‡	3	1	18	4	11	3	15	2	Calm 20	100

Direction and velocity of winds at Allentown-Bethlehem airport, 1929-1938

Miles per hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total observations	%
4–15__	4019	1429	6592	1249	2927	600	1952	567	3925	1951	12021	2104	4915	1249	6227	1493	53220	64
16–31__	463	162	730	172	246	61	166	62	295	170	823	445	1819	914	3076	582	10186	12
32–47__	10	1	35	13	7	1	7	3		5	4	9	96	58	142	15	406	1
Over 47___											1		6				7	‡
Calm_																	19263	23
Total obs.	4492	1592	7357	1434	3180	662	2125	632	4220	2126	12849	2558	6836	2221	9445	2090	83082	
%_____	5	2	9	2	4	1	3	1	5	3	15	3	8	3	11	2	Calm 23	100

Maximum winds, miles per hour, at Allentown-Bethlehem airport, 1929-1938 *

Year	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	MAX.
1929	♯		W 48 11 hr.⊙	NE 40 9 hr.	SW 40 12 hr.		♯	NW 36 12 hr.⊙	♯	♯	♯	♯	48
1930		WSW 32 13 hr.	SSW 38 8 hr.⊙	WNW 38 15 hr.						NW 36 12 hr.	NW 37 24 hr.		38
1931	NW 39 14 hr.	WNW 40 5 hr.	ENE 44 10 hr.	W 36 1 hr.		NW 46 17 hr.			NW 32 11 hr.	NNW 34 23 hr.	NW 38 15 hr.	W 45 17 hr.	46
1932	W 39 14 hr.	WNW 35 2 hr.	W 49 15 hr.	W 32 10 hr.⊙					NW 32 19 hr.	W 34 15 hr.	NNW 36 13 hr.⊙	N 36 21 hr.	49
1933	W 40 17 hr.	W 49 12 hr.	W 45 14 hr.	W 36 22 hr.	NNW 32 4 hr.	NW 46 3 hr.		E 36 22 hr.		NW 38 11 hr.	W 36 16 hr.	W 46 12 hr.	49
1934	NW 45 9 hr.	NW 38 1 hr.	SW 42 17 hr.				N 35 17 hr.⊙					WSW 36 8 hr.⊙	45
1935	WNW 34 22 hr.		W 36 13 hr.	NE 36 11 hr.⊙							N 36 14 hr.	NW 32 11 hr.	36
1936	NE 32 19 hr.	NE 32 9 hr.⊙	NW 45 10 hr.	WSW 33 23 hr.	W 35 21 hr.		WNW 35 18 hr.	NW 40 18 hr.⊙		NW 36 20 hr.	NW 32 14 hr.	ESE 40 22 hr.	45
1937		SE 32 24 hr.	SW 32 8 hr.	NE 36 2 hr.⊙			SW 48 18 hr.						48
1938	SSW 40 5 hr.	WNW 36 16 hr.⊙	WNW 32 24 hr.	WNW 35 24 hr.	WNW 32 11 hr.				NW 32 16 hr.		W 50 13 hr.		50
Maximum	45	49	49	40	40	46	48	40	32	38	50	46	50

* Time of observation is indicated with day divided into 24 periods of observation. 10 hr. is 10 A. M. and 22 hr. is 10 P. M., etc.

♯ Indicates no records for these months.

⊙ Also other directions and hours.

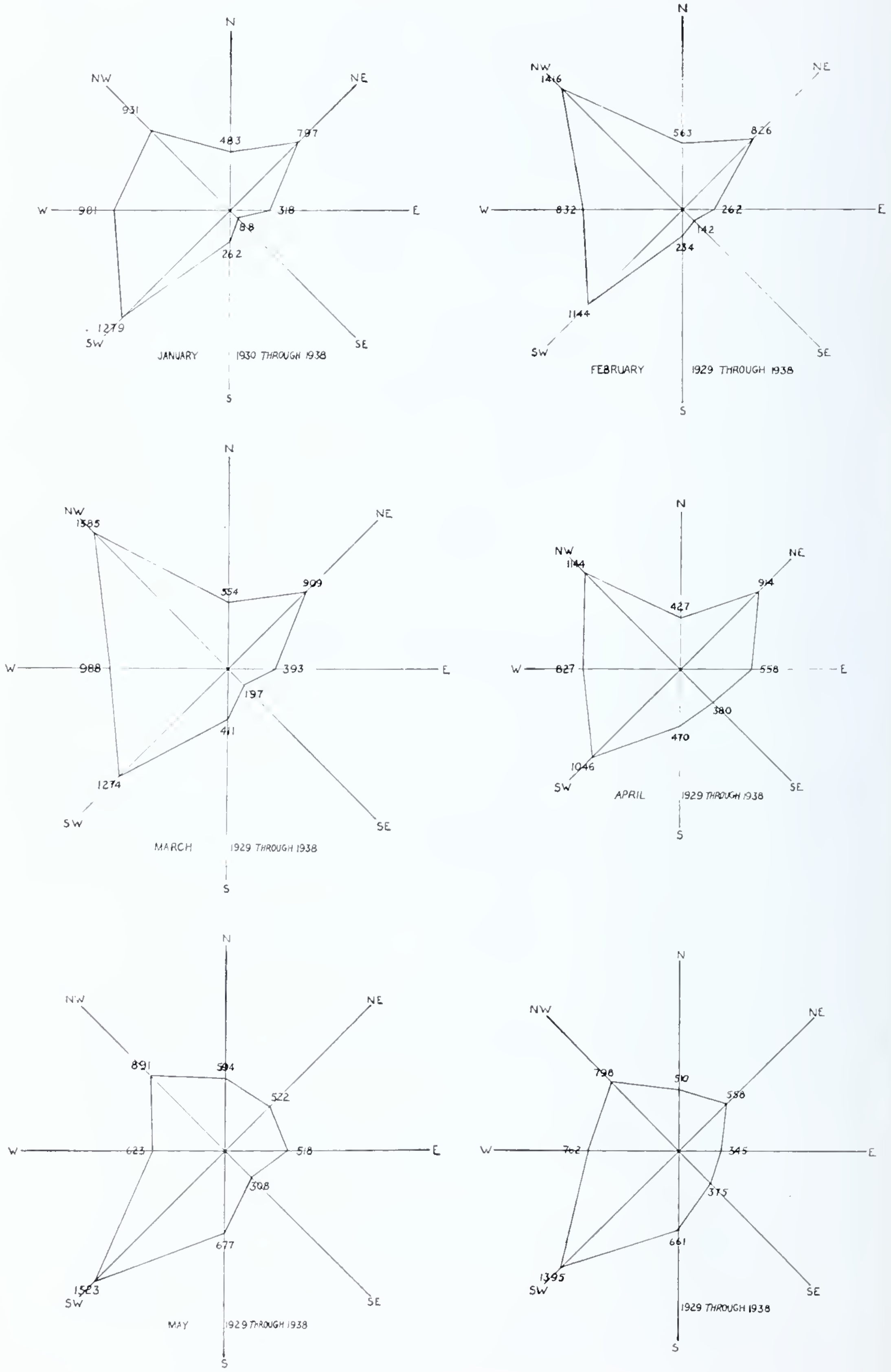

Figure 2. Wind diagrams for January to June.

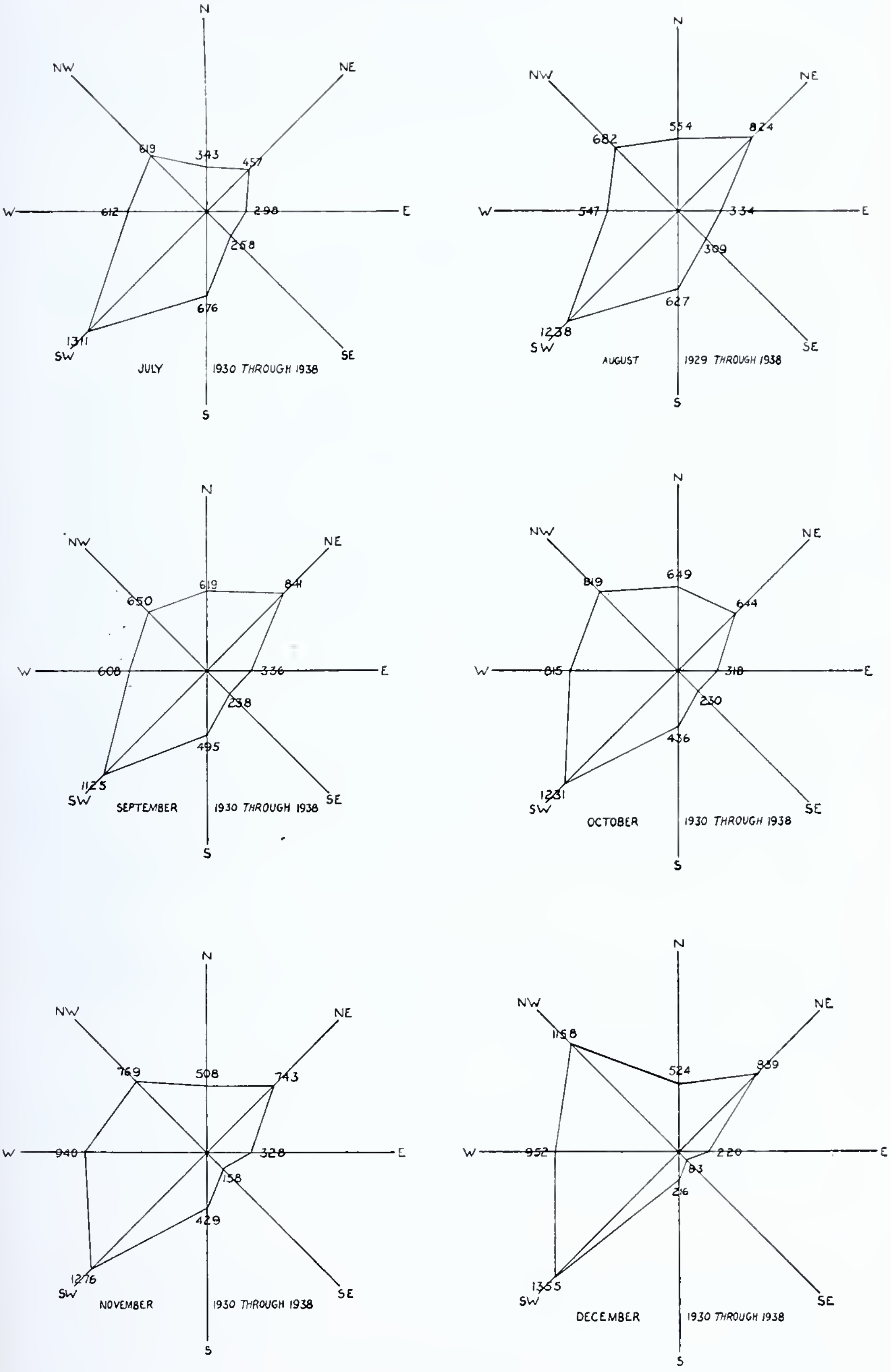

Figure 3. Wind diagrams for July to December.

Storms

Two kinds of storms bring practically all the precipitation in the Lehigh Valley and effect the greatest changes in temperature and in the winds. These are the extratropical cyclones and the thunderstorms. In some respects these are not definitely separable as the thunderstorms may be a part of the larger cyclones.

Extratropical Cyclones

The extratropical cyclones are great spirally whirling masses of air several hundred miles in diameter that sweep across the country from west to east during most of the year, but especially noticeable during the winter. On the daily weather map they appear as areas of low pressure and are generally called ''lows.''

The approach of one of the storms is marked by a gradual but decided drop in the barometric pressure, the winds shifting to the east or northeast, increasing humidity, increasing cloudiness, and generally a slight increase in temperature. So regular are these changes that one can make fairly accurate predictions of an approaching storm from twelve to twenty-four hours in advance of the beginning of precipitation. The wind may blow from the northeast or east for a day or more before rain or snow starts to fall. Precipitation, having started, continues more or less steadily as long as the wind remains in the east and the barometer is falling. Sometimes in late fall, winter or spring the storm may last two to three days, or rarely even longer, and the rain from a single storm amount to several inches. During the summer these storms are much less pronounced and one that appears fairly well developed in the central part of the country may disappear before reaching the Atlantic border. The winds in these storms are not often strong enough to do much damage in Pennsylvania although along the ocean these east or northeast winds result in considerable shore erosion and damage to coastwise shipping. The strength of the winds is determined mainly by the rapidity with which the barometer falls.

The ending of one of these storms is marked by the rise in the barometer; the cessation of precipitation and gradually clearing skies; decided drop in temperature producing, when extreme, what are known as ''cold waves;'' and the shifting of the winds to the northwest or southwest and marked increase in their velocity.

In normal winter weather a storm of this kind passes through eastern Pennsylvania about every four or five days, but there is much variation. In the summer the ''lows'' normally move more slowly and are less pronounced. Occasionally such a storm passes with all the usual pressure and temperature changes but without precipitation.

Thunderstorms

Thunderstorms are a characteristic feature of the summer months in the Lehigh Valley, although they have occurred in every month of the year. During the growing season, and especially in July and August, practically all the precipitation may be received from storms of this kind; the extratropical cyclones may be scarcely noticeable. Thunderstorms also commonly accompany the extratropical cyclones and are most frequent when the southeast quadrant of the larger storm passes through a region. Although many thunderstorms are extremely local, with a path only a few miles wide, other single ones may extend over a large part of the State. The rainfall from a single storm may be excessive and cause disastrous local floods. The winds also reach occasionally velocities of forty to fifty miles per hour and much damage is done to trees and property. The annual property loss due to lightning is also no small factor and a few deaths each summer from this cause are not unusual. Notwithstanding their destructiveness, thunderstorms are the salvation of the crops in the Lehigh Valley each summer.

The frequency of thunderstorms is extremely variable. During periods of high temperature they may be an almost daily occurrence, although not often in exactly the same place day after day. At other times they may be quite rare. They most commonly break in the late afternoon or early evening but do occur at almost every hour of the day. After the thunder, lightning and wind have subsided the skies may clear in just a few minutes, but occasionally gentle rain may continue for many hours.

The passage of a severe thunderstorm almost invariably results in a decided drop in temperature. Within a few hours the temperature may fall as much as thirty to forty degrees, passing from excessively hot to abnormally cool. Prolonged excessively hot periods are apt to end with heavy thunderstorms followed by decidedly chilly weather.

Other Storms

The Lehigh Valley is visited occasionally by other types of storms, such as the West Indian hurricanes and tornadoes. The former, originating in the West Indies where they are occasionally extremely destructive, sometimes sweep up the Atlantic Coast and bring heavy rain and high winds. By the time they reach Pennsylvania they have lost much of their force and are similar in almost every respect to the extratropical cyclones previously described. When they do pass over eastern Pennsylvania they bring extremely heavy rain and unusually low barometric pressures. In the West Indian storm of August 22-24, 1933, which passed over the region, the rainfall amounted to 5.76 inches. The resulting flood did much damage. These hurricanes move very slowly in Pennsylvania so that rain may fall almost continuously for three or four days.

Tornadoes with their whirling funnel-like clouds are rare in this section, but have occurred. They are merely thunderstorms concentrated to a diameter of only a few hundred feet. Within that area the twisting winds attain hurricane velocity sufficient to raze almost any structure in their path.

PHYSIOGRAPHY

By Benjamin L. Miller

The most casual observer crossing Lehigh County from north to south notes differences in the topographic features, whereas a person traversing the county in a west-east direction notes few changes. It is the function of the geologist (geomorphologist) to differentiate, classify, name and explain these resemblances and differences. Numerous investigators have studied these forms in Lehigh County or in other parts of the Appalachians. Because of the wide extent of each physiographic type represented in the region, studies made in somewhat distant sections are pertinent to this discussion.

There is general agreement regarding the main features but not in the minor divisions and in the nomenclature. The classification of Fenneman,* adopted by the U. S. Geological Survey, is mainly followed in this report.

According to this usage, Lehigh County constitutes a small portion of the Appalachian Highlands which extends from Canada to central Alabama and from the Coastal Plain on the east to the Interior Plains on the west. This is divided into provinces and these in turn into sections. Lehigh County contains portions of the following divisions:

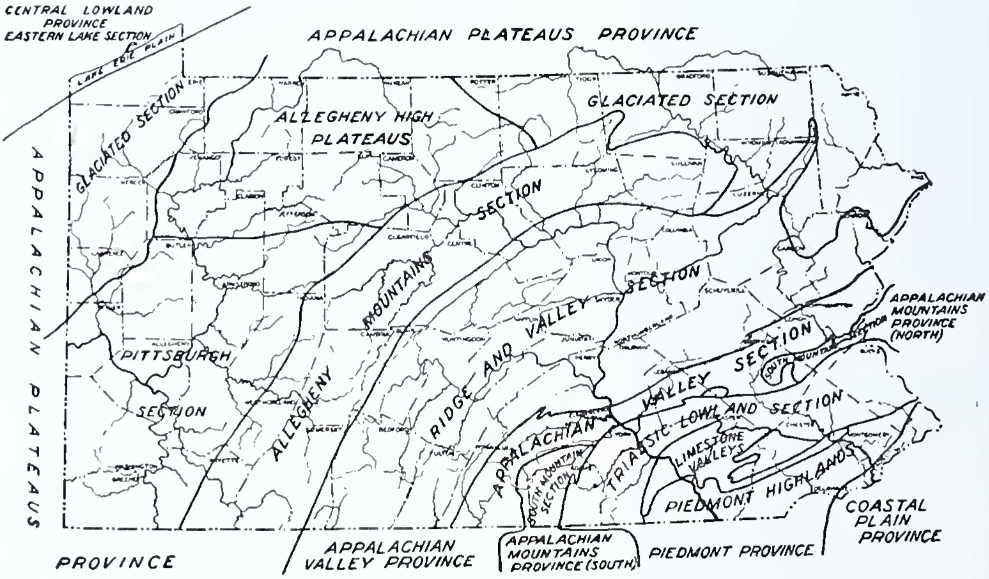

Figure 4. Physiographic subdivisions of Pennsylvania.

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* Fenneman, N. M., Annals Assoc. of Amer. Geographers, vol. 18, pp. 262-353, 1928.

Physiographic divisions of the Appalachian Highlands represented in Lehigh County

Province	*Section*	*Distribution*
Piedmont Lowlands	Triassic Lowlands	Poorly represented in non-characteristic form in southeastern portion of Lower Milford and Upper Saucon Townships.
New England Uplands (Also called *Older Appalachians*).	Reading Prong (Also called *Appalachian Mountains*).	Steep, hills or ridges of crystalline rocks, irregular in form, separated by flat-bottomed valleys of limestone. Geographically these are South Mountains or the Durham and Reading Hills. This area lies south of Allentown, Emmaus, Macungie and Alburtis.
Ridge and Valley Province* (Also called *Newer Appalachians* and *Folded Appalachians*).	Portion between South Mountains (Durham and Reading Hills) and Kittatinny (Blue) Mountain is called *Appalachian Valley* and *Lehigh Valley*.	Areas of limestones and slates.
	Kittatinny (Blue) Mountain.	Ridge of Silurian (Shawangunk) sandstones and conglomerates.

* Some writers have limited the Ridge and Valley division to that portion of the Appalachian Highlands lying between the Allegheny Mountains (or Plateau) and the Appalachian Valley. According to this usage, Kittatinny (Blue) Mountain is the only part of the Ridge and Valley province present in Lehigh County.

Topographic Features

The main topographic features of Lehigh County are so distinct that they were noted by the early explorers and travelers, some of whom offered fantastic explanations as to their origin. In recent years trained investigators have studied them in detail and have disagreed in so many points that the writer enters this field of controversy with extreme reluctance. He therefore presents descriptions of the phenomena and the theories of different investigators. Although preference for particular views may be shown, an attempt is made to leave the acceptance or rejection of various ideas to the individual reader and to future students.

EROSION SURFACES

When that stimulating and earnest student of land forms, William Morris Davis, wrote his articles on the streams of Pennsylvania and New Jersey in volumes I and II of the National Geographic Magazine he initiated the scientific investigation of the topographic features of this region. Before Davis wrote, there were occasional notes by other geologists. In 1883 J. P. Lesley * called attention to three prominent plains (planes) in the region. Of Kittatinny (Blue) Mountain he said, "Its crest a nearly horizontal line everywhere about the same height (1,500 to 1,600 feet above the sea)." (p. 23.)

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* Pennsylvania 2d Geol. Survey Rept. D 3, vol. 1, 1883.

In the following quotations he describes the slate and limestone belts of Northampton County. His descriptions are equally applicable to Lehigh County: "The slate belt of Northampton County stretches from the Delaware to the Lehigh for seven miles south of the mountain. It is (a) region of low flat-topped hills, trenched by a multitude of small valleys, and when looked down upon from the mountain, appears like a great plain, which it really is." (p. 27.) "*The limestone plain* of Northampton County is about seven miles wide, and elevated * * * about 400 feet above tide; its hill tops sometimes reach 450 feet. This plain is intersected in every direction by gently sloping vales." (p. 36.)

A mere casual examination of the topographic map reveals four sharply distinct topographic regions. A fifth one is poorly represented. From north to south these are Kittatinny Mountain, the slate region, the limestone valley, and the hills of the southern part of the county. These will be described in turn. The first three belong to the Ridge and Valley Province and the fourth to the Reading Prong of the New England Uplands. The fifth is the Triassic Lowlands.

In some regions the topographic features have little relation to the stratigraphy. In Lehigh County, however, each of the erosion surfaces (peneplanes?) is almost completely confined to a particular formation or group of formations. This has resulted in a discussion as to whether the successive more or less level surfaces should be designated as peneplanes or not. At this point they will be described as topographic features only and called erosion surfaces. Their origin will be discussed on later pages.

Kittatinny (Blue) Mountain.—This even-crested mountain ridge, visible on a clear day for long distances, is the most regular and most impressive topographic feature of the entire region. Viewed from the distance, it has the appearance of the edge or the escarpment of an elevated plateau. When one climbs it and finds that the mountain is a narrow ridge with the top scarcely wider than one-fourth mile any place and generally much narrower, the mountain then appears as a barrier ridge. The hard Tuscarora conglomerates and sandstones forming the mountain dip to the northwest at angles varying from 30° to 60°. The Martinsburg shales beneath dip in the same direction, likewise at various angles. The contact between the two formations, seldom observable on account of the hillside talus, is generally about half way up the southern slope.

The crowding of the contours shown on the map indicates the steepness of the slopes. They can be climbed by the pedestrian only with considerable difficulty. The two roads that cross the mountain ascend by diagonal and zigzag courses and finally cross the crest in notches or minor gaps. No stream crosses the ridge west of Lehigh Gap within the county, so that it forms a prominent divide between the tributaries of the Lehigh River and between Lehigh and Carbon Counties. The mountain is a single ridge with a remarkably straight trend to the west-southwest. Although the general appearance of the mountain on the skyline is that of a straight line, closer inspection and the examination of the map shows considerable variation in elevations. Ignoring the gaps or notches, the crest varies from 1,400 to 1,600 feet above sea level. Some persons have been inclined to suggest two levels of different altitude but since there is no marked separation between the two, it seems preferable to regard these varying elevations as due either to crustal warping or to varying amounts of erosional degradation.

Kittatinny (Blue) Mountain may be said to typify what is regarded as a somewhat lowered peneplane remnant, the remaining portion of an extensive plane of erosion that at one time extended throughout the entire Appalachian region. It was once believed that during Cretaceous time the tops of the folded Appalachians were worn down to base level. More recently the date for this leveling has been placed in middle or late Tertiary time. Subsequent elevation has permitted the removal of the softer, less resistant rocks on both sides. Other similar ridges lie to the northwest of Kittatinny Mountain in adjoining counties. In some places there are several parallel ridges separated by steep-sided valleys. In every case the ridges are composed of hard resistant rocks and the valleys cut in shales or in a few places in limestones. Along the Susquehanna River the continuation of Kittatinny Mountain is called First Mountain and is followed northwestward by Second and Third mountains.

Slate (Shale) Region.—The ordinary traveler in the region can scarcely fail to note comparatively flat-topped stream divides in the northern part of the county where the rocks are mainly the Martinsburg shales and slates but with some associated sandstones. In the southern portion of the band these fairly level hilltops have a general elevation of 650 to 700 feet, but going north toward Kittatinny (Blue) Mountain similar divides rise above 800 feet. Where the sandstones are well-developed, the crests rise well above 900 feet. A knob near the western end of Shochary Ridge is 1,060 feet above sea level and the apex of the ridge south of Slatington is 1,000 feet. In Lehigh County the accordance of these fairly level hilltops is less noticeable than in adjoining regions. Nevertheless the entire region would present a gently rolling surface gradually rising toward the north, if the steep-sided narrow stream valleys could be filled, with the sandstone ridges rising above the level surface as monadnocks.

The streams of the region, especially the headwater tributaries of Jordan and Coplay creeks flowing into the Lehigh River and Mill and Ontelaunee creeks flowing westward into the Schuylkill, have intricately carved the originally continuous upland, making it a decidedly uneven surface. They have cut their valleys to depths varying from 100 to 400 feet.

The hillsides of the region are characteristic. The slopes are symmetrically rounded near the tops of the divides and steep in proximity to the streams. Anyone familiar with this type of topography could scarcely fail to identify it as characteristic of a slate region and distinctly unlike anything to be seen in other portions of the county.

The characteristics of the streams of the slate belt are distinctive. They are described on a later page.

Limestone Valley.—That part of the county occupied by the Cambrian and Ordovician limestones possesses a distinctly different appearance. The interstream areas are broad and so nearly flat that in many places one can not note any irregularities of more than a few feet for distances of several miles. The streams are few and commonly have very gentle valley slopes. The average elevation of the divides is about 400 feet. A few hills rise 20 to 60 feet above, and some sinks are 20 or more feet below the general level. The Lehigh River and the lower courses of the tributaries are about 200 feet below the general level.

The relatively few surface streams as compared with the slate region, and the numerous sinks bear witness to the development of an extensive underground drainage system.

Prongs or outliers of both slate and crystalline rocks break the continuity of the limestone areas. The best illustrations are Huckleberry Ridge and Haas Hill composed of slate, and Lock Ridge and South Mountain composed of gneisses. Saucon Valley is separated from the other limestone areas of the county, but is continuous with the limestone belt of Northampton County by means of a narrow pass through which Saucon Creek flows to enter the Lehigh River. A small, completely detached hill of crystalline rocks is cut by Little Lehigh Creek in the vicinity of Western Salisbury Church. All these occurrences of less soluble rocks in the limestone belts rise conspicuously above the level of the limestone floor.

South Mountain.—South Mountain and its offshoots present a striking contrast to the topographic features previously described. They are part of the Reading Prong of the New England Uplands and are composed mostly of pre-Cambrian crystalline rocks of various kinds but with intervening, partly enclosed valleys floored with Paleozoic sediments, especially limestones. This belt is continuous with the New England Physiographic Province which comprises practically all the New England States. The narrow prong widens to six to eight miles at the Schuylkill in the vicinity of Reading where the Triassic rocks come in contact with the Paleozoic limestones through an overlap. Beyond the Susquehanna River, the crystalline rocks again come to the surface and continue southwestward and southward to Georgia as the Blue Ridge Province.

Several different names have been applied to this belt of hills. The Second Geological Survey of Pennsylvania used the name Durham and Reading Hills. The mountain paralleling the Lehigh River between Bethlehem and Allentown has been called South Mountain and also Lehigh Mountain. Both of these names have also been applied to other portions of the belt. Names have been given to individual mountains also.

The use of the term South Mountain in this region sometimes results in confusion as it has been used more commonly for the mountains bounding the Appalachian Valley on the southeast in Adams and Franklin counties. Local usage, however, is followed rather than the proposal of a new name or the restoration of uncommon names.

As shown on the map, few generalizations can be made concerning the size, shape, height, or direction of the hills of this province.

Elongation in a west-southwest direction and separation by narrow valleys of like trend is noticeable although there are exceptions. Some of the ridges are several miles long; some hills are isolated, rounded. Flat-topped eminences are lacking and no correlation of the hilltops can be made. East of the Delaware River in New Jersey and continuous with this section is the fairly flat-topped Schooley Mountain. Presumably, at one time such a feature may have been present in Lehigh County but it has now disappeared by differential erosion.

The tops of the hills in this area range from 500 to somewhat more than 1,000 feet above sea level. Bauer Rock on the top of the mountain southeast of Allentown has an elevation of 1,038 feet and the mountain south of Macungie slightly exceeds 1,080 feet. The slopes of the mountains are generally covered with talus, in some cases extremely large blocks. The thickness of the talus can seldom be determined, as excavations for new structures on the lower slopes rarely encounter the solid rock in place. Anomalous conditions can be found in the region, such as hard fresh rocks outcropping as steep ledges; rocks weathered in place to such an extent that they can be dug readily with pick and shovel to the depths of 40 or 50 feet; and talus composed of both fresh and decomposed rocks. On the hill slopes in many places excellent examples of spheroidal or concentric weathering (exfoliation) of angular blocks of gneiss can be found. They are as spherical as though they had been rounded by stream transportation.

In many places north slopes are steeper than south slopes. This is explained as the result of frost action. On the northern slopes the soil water may be frozen and thawed only a few times during each winter but on the southern sides numerous alternate freezings and thawings each season have accentuated the results of frost work and the slopes have been reduced.

Triassic Lowlands.—If the physiographic divisions of the region are definitely confined to stratigraphic geologic formations, the division termed the Triassic Lowlands is represented in that segment of Flint Hill that appears in the extreme east part of Lehigh County and the red shale and trap rock (diabase) hills of Upper Saucon and Lower Milford townships. If, on the other hand, the separation is made on topographic characteristics, this division is not represented in the county. Flint Hill, the hill of Triassic conglomerate southwest of Coopersburg and the trap rock hills of Lower Milford Township topographically are a part of the Reading Prong of the New England Uplands and the area about Coopersburg underlain by Triassic shales is not separable topographically from the limestone area of Saucon Valley. Flint Hill rises to 1,008 feet and some of the other hills exceed 900 feet. It is readily apparent that the Triassic belt of Lehigh County is not typical of the larger band of Triassic rocks that sweeps across southeastern Pennsylvania and is so prominently developed in Bucks, Berks, and Montgomery counties. It is therefore questionable as to whether the physiographic division of the Triassic Lowlands should be regarded as present in Lehigh County, regardless of the fact that Triassic rocks are present.

Origin of the Physiographic Features

In the explanation of the physiographic divisions just described, the limitation of space precludes the evaluation of each of the contributions that have been made and it seems inadvisable to do more than name the persons who have contributed to this problem. An attempt has been made to include all the published researches in the Bibliography and the reader is referred to that chapter for titles and places of publication. The most important articles have been written by J. P. Lesley, F. Prime, W. M. Davis, R. D. Salisbury, J. Barrell, D. W. Johnson, M. R. Campbell, G. W. Stose, F. Bascom, E. B. Knopf, A. I. Jonas, G. H. Ashley, K. Ver Steeg, F. Ward, W. S. Tower, E. W. Shaw, N. M. Fenneman, H. A. Meyerhoff, and E. W. Olmsted. It would be difficult to decide which of these deserves most credit and the order in which they have been mentioned means nothing. Several are in general agreement although probably no two are in complete agreement.

Although there are differences of opinion concerning the origin of the erosion surfaces just described, the common usage is followed by designating them as peneplanes and assigning to them geographic names. The one represented by the crest of Kittatinny (Blue) Mountain has been named the Schooley peneplane; the prominent erosion surface of the slate region is the Harrisburg peneplane; and the limestone surface is named the Somerville peneplane.

Formation of the Schooley peneplane.—Probably all the investigators believe that at some time in the past all this region and most of the entire Appalachian belt of eastern United States was reduced to a base level of erosion that was near sea level. This occurred long after the Appalachian Revolution had thrown the original horizontal rocks into great folds by which certain portions were uplifted thousands of feet above other sections. The base level of erosion was developed by the truncation of the tops of the folds and the formation of a featureless plane with little or no distinction between hard and soft rocks. This base level is known as the Schooley peneplane, named for Schooley Mountain in New Jersey. Across this plane sluggish streams took their winding courses to the Atlantic Ocean.

The next event was an uplift of the entire region without folding or major faulting. The movement is believed to have been almost vertical. It was not equally great in all places, with the result that the old erosion surface was somewhat warped.

The date of this extensive peneplanation has been assumed generally to have been during Cretaceous time and the debris removed by the streams was deposited in the nearby Atlantic Ocean. This debris forms the extensive Cretaceous strata of the Coastal Plain. In recent years the idea of a much younger age has been advanced until now Ashley [1] regards the peneplanation to have been completed no longer ago than late Pliocene time. Strong arguments are presented in support of his view. At this time the date of peneplanation may be said to be undetermined.

Another new conception of past events which essentially alters the older ideas was suggested by Barrell and recently elaborated by Johnson.[2] He suggests that peneplanation was followed by a submergence and the deposition of a mantle of coastal plain sediments covering a large part, if not all, of the peneplane. He presents an array of facts to show that the present drainage system can best be explained by a former cover of this sort. The present streams are believed to have originated when the region was later uplifted. They eventually cut through these unconsolidated sediments and, maintaining their positions, cut channels in the underlying Paleozoic rocks. This explains the manner in which the major streams cut across both hard and soft rocks alike with little regard to structures. Johnson's theory is beyond proof or denial as no trace of the extended coastal plain sediments remains. It appeals to some geologists but as yet seems to have been received with much skepticism.

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[1] Ashley, G. H., Geol. Soc. Amer. Bull., vol. 46, pp. 1395-1436, 1935.

Ver Steeg[3] presents one bit of evidence as opposed to this idea of a cover of coastal plain sediments.

> In the majority of cases it was found, as a result of profile and field studies of Appalachian ridges in Pennsylvania and New Jersey, that for long distances on either side of water gaps and major wind gaps, ridge crests representing the upper (Schooley or Kittatinny) peneplane descend faintly toward the major stream courses, indicating that these streams were superposed in a cycle earlier than the Schooley (Kittatinny) and held their courses throughout Schooley (Kittatinny) time. . . . The presence of high level, broad, shallow valleys on the Schooley (Kittatinny) peneplane, coincident with the present courses of the larger rivers, is not consistent with the theory that these streams were incised in this peneplane from an immediately overlying coastal plain cover. (p. 218.)

L. and C. Dryden have recently studied the heavy minerals of the Coastal Plain formations of New Jersey and have concluded that "the Coastal Plain sediments were derived essentially from crystalline rocks, not from the Paleozoic or Triassic. Therefore, the writers believe that the Piedmont and the New Jersey Highlands were never covered by Cretaceous or Tertiary sediments.[4]

The evidence presented appears to be valid in that the Coastal Plain heavy minerals show a close relationship to the crystalline rocks of the Piedmont, thus indicating their origin. With the entire Piedmont covered with such an extension of the Coastal Plain as suggested by Johnson that source for the heavy minerals would not have been possible.

The name Kittatinny was long applied to this peneplane of erosion. Kittatinny (Blue) Mountain, with its comparatively flat top caused by the truncation of steeply dipping hard siliceous rocks to about the same level, has been assumed to constitute the existing remnants of this old plane. It is now generally believed that the peneplane developed on Schooley Mountain is likewise a part of this old base level plane. It is at a lower level but the dip of the plane to the southeast, it is thought, would bring the two together if the intervening low-lying region could be refilled to its former condition. Stose[5] correlated the Kittatinny and Schooley peneplanes and suggested a post-Cretaceous normal fault to account for the differences in level of the tops of Kittatinny and Schooley (N. J.) mountains. Other workers do not consider such a hypothesis necessary. The peneplane of Schooley Mountain was earlier named the Schooley peneplane and therefore gains priority over Kittatinny. Accordingly, if one name is dropped it must be the later one and we therefore adopt the name of Schooley peneplane for the flat truncated surface of Kittatinny Mountain.

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[2] Johnson, D., Stream Sculpture on the Atlantic Slope. 142 pp., Columbia Univ. Press, N. Y., 1931.

[3] Ver Steeg, H., Annals New York Acad. Sci., vol. 32, pp. 87-220, 1930.

[4] Lincoln Dryden and Clarissa Dryden, Geol. Soc. Amer. Bull., vol. 51, pp. 1993-1994, 1940.

[5] Stose, George W., Possible post-Cretaceous faulting in the Appalachians: Geol. Soc. America Bull., vol. 38, pp. 493-504, 1927.

In most of the published articles it is assumed that the present top of Kittatinny Mountain is substantially the same surface as that develop during peneplanation. Ashley[6] has presented evidence to support his belief in a great reduction by erosion during the period of time since the uplift of the Schooley peneplane. He estimates a reduction of hundreds of feet, perhaps as much as 1,200 feet in the central part of the State but less in this section. Dr. Ashley has called attention to an oversight of former workers and a very important one, yet the writer is not at this time able to reconcile this great reduction with the even surface now remaining. If the strata were homogeneous in composition and structure, one might believe that they would be reduced in such uniformity as to preserve the old peneplane characteristics. However, the variations in both composition and structure are too great for him to believe that Kittatinny Mountain has been lowered a thousand feet or even a few hundred feet below the old Schooley peneplane. As he has viewed and admired from the Lehigh University campus day after day for over thirty years the even skyline of Kittatinny Mountain on the distant horizon, he has speculated on its origin and is still inclined to believe that the top of the mountain, especially where it preserves a flat surface from a fourth to half a mile in width, has not been substantially lowered from the old Schooley peneplane surface. The fresh appearance of the glacial striæ on some of the hard ledges on the crest of the mountain east of Fox Gap, Northampton County bears witness to the slow rate at which these strata are being destroyed.

The Schooley peneplane is not observable in the South Mountains in Lehigh County. They seem to have been reduced below the old peneplane surface and at varying amounts. The higher points may be only slightly below but they fail to preserve any of the peneplane features.

Formation of the Harrisburg peneplane.—Disregarding Johnson's theory of a marine submergence of the Schooley peneplane, we may continue the story following the vertical elevation. The uplift resulted in renewed activity of the streams and more rapid removal of the products of weathering. Under such conditions, the less resistant rocks were the ones that suffered most. The first uplift of the peneplane was of the magnitude of 700 to 900 feet. Eventually all the softer rocks, the limestones and slates, are believed to have been lowered to a new base level whereas the crystalline rocks of South Mountain and the hard siliceous rocks of Kittatinny Mountain suffered little reduction.

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[6] Ashley, G. H., op. cit.

This second peneplanation, which was only a partial one, embraced only that area between Kittatinny Mountain and the crystalline rock portions of the South Mountains. This is the peneplane represented by the level surfaces of the slate region and has been named the Harrisburg peneplane from its development in the Harrisburg region. Later, Campbell,[7] who had originally proposed the name Harrisburg, suggested the term Chambersburg for this peneplane because of confusions that have resulted. In this volume, however, the original name is retained for the present.

The sandy strata of the Martinsburg formation, such as Shochary Ridge and the hills south of Slatington, were not entirely reduced to the new base level and they now appear as hills rising noticeably above the Harrisburg peneplane. Miss Bascom [8] suggests that these elevations constitute the remnants of an intermediate base level which she designates the Honeybrook peneplane. In this region particularly there seems to be insufficient evidence for the existence of such a widespread plane of erosion between the Schooley and the Harrisburg.

Formation of the Somerville peneplane.—Renewed uplift once more rejuvenated the streams and increased the removal of material from the region. The limestones, because of their destruction by both physical and chemical agents, are the ones which suffer most, and the limestone areas are the first to be reduced to base level. It is believed that they were so lowered to a new base level whereas the slates and harder rocks still preserved the original characteristics of the Schooley and Harrisburg peneplanes with only minor changes.

While the limestone areas were being base-leveled the streams of the slate region were sinking their valleys in the old peneplaned surface. Some of the headwater streams of Jordan Creek had developed meanders as they flowed across the nearly featureless plain preceding this third uplift. They accordingly cut down and entrenched their meanders. These entrenched loops of the streams of the slate areas furnish evidence of this third stage of peneplanation and subsequent uplift. A further uplift occurred before the base level had been extended and the slates and other harder rocks lowered to the new base level developed in the limestone areas.

The peneplane developed on the Cambrian and Ordovician limestones of the region, and on which West Bethlehem, Allentown, Emmaus, Macungie, and Alburtis are built, is known as the Somerville peneplane. At times it has locally been called the Bethlehem peneplane. The features of this peneplane have been described on an earlier page. It is of much less extent than either of the other peneplanes and, being younger, has undergone less change subsequent to its formation.

Some of the base-leveled streams on the Somerville developed meanders, as did the tributaries of Jordan Creek on the Harrisburg peneplane. When a later uplift occurred the streams maintained their location and cutting downward produced entrenched meanders. These are shown nicely in the loops and bends of Little Lehigh Creek southwest of Allentown. This creek has prominent bluffs of limestone in many places. The occasional flood plains indicate that the stream is beginning a new cycle of peneplanation, but has made little progress as yet in the reduction of the limestone areas to a new level of erosion.

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[7] Campbell, M. R., Chambersburg (Harrisburg) Peneplane in the Piedmont of Maryland and Pennsylvania: Geol. Soc. Amer. Bull., vol. 44, pp. 553-573, 1933.

[8] Bascom, F., Jour. of Geol., vol. 29, pp. 540-559, 1921.

Are There One, Two Three or More Peneplanes in Lehigh County?

In the foregoing pages, descriptions have been given of three separate and distinct peneplanes. This is the view held by the writer, although he recognizes the value of the arguments advanced by other workers who interpret the existing topographic features differently.

There has been repeated questioning of the existence of the Somerville peneplane. The writer, himself, for several years maintained that the development of this flat surface of erosion did not result from any uplift of the region and subsequent reduction by stream action, but was simply the lowering by solution of that portion of the Harrisburg peneplane underlain by limestone. Ward[9] has furnished an excellent discussion of the problem.

The fact that the Somerville peneplane is distinctly limited to the limestone areas is the principal argument against the generally accepted view. In addition, the numerous examples of solution such as sink holes, underground channels, and caves and the absence of stream gravels over the uplands furnish corroborative evidence.

The evidence for the Somerville peneplane of fluvial erosion accompanied by solution and the development of a base level of degradation is the regularity of the surface. The various rocks in which the plane has been cut have been folded, faulted and shattered locally to a remarkable degree. The writer doubts that the region could have been so regularly reduced by solution alone without base leveling. These variables must have influenced the rates of lowering by the underground circulation and should have developed a much more irregular surface than now exists. Of course, no one will deny that solution has been an important agent. The question does not admit of a positive decision and it is expected that different points of view will continue.

Recently, Ashley[10] has proposed the elimination of all but the Schooley peneplane of fluvial base level erosion. He believes that all the present topographic features are the result of differential erosion. The Cambro-Ordovician limestones were least resistant, the Martinsburg slates somewhat more and the Shawangunk conglomerates and sandstones most. Therefore, the surfaces described as the Harrisburg and Somerville peneplanes do not imply different stages of base-leveling and subsequent uplifts.

A similar objection to that offered for the elimination of the Somerville peneplane of stream erosion (and solution) can be advanced against Ashley's proposal. With the complicated structures and varying hardness of the strata of both the Martinsburg slates and the Cambro-Ordovician limestones, it does not seem to the writer that differential erosion unaccompanied by fluvial erosion base-leveling would have developed the even surfaces of the uplands over extensive areas such as are present in this district. Further, the entrenched meanders that are conspicuous in the shale areas in many places in the State and in some localities in the limestones imply the development of meandering streams on a more or less peneplaned surface, followed by uplift and entrenchment. Examples of these in Lehigh County are described above and also in the descriptions of individual streams.

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[9] Ward, F., The role of solution in peneplanation: Jour. of Geol., vol. 38, pp. 262-270, 1930.

[10] Ashley, George H., Studies in Appalachian Mountain sculpture: Geol. Soc. of Amer. Bull., vol. 46, pp. 1395-1436, 1935.

It is left for the individual reader to choose the explanation which most appeals to him as the correct one. All will agree that all surfaces, no matter how flat, are being lowered and modified continually but whether the existing level surfaces lower than the Schooley peneplane have been developed by differential erosion or by several periods of base-leveling and broad crustal uplifts is the question. It is receiving serious attention at the present time.

Before leaving the question of peneplanation, it may be well to make reference to the hypothesis proposed by Barrell [11] in 1913 and on which he was at work at the time of his death in May 1919. His uncompleted manuscript was published [12] after his death. He suggested that the level surfaces described as peneplanes of fluvial erosion may have been the result of marine denudation at times when the ocean transgressed the continent to a greater extent than generally believed. This idea has not received much support. One can not know what Barrell's final conclusion may have been but with the keen analytical mind which he possessed it is thought that he would have made important contributions. He began his geological investigations while a student in Lehigh University and was well acquainted with the geomorphological problems of this region.

E. B. Knopf [13] has described 10 erosion surfaces in Pennsylvania, of which 7 are represented in Lehigh County. In order of decreasing elevation and age they are (1) Kittatinny (1,660 feet), (2) Schooley (1,400 to 1,300 feet), (3) Mine Ridge (1,100 to 1,000 feet), (4) Honeybrook (900 to 840 feet), (5) Sunbury (700 to 600 feet), (6) Harrisburg (Bryn Mawr?) (560 to 500 feet), and (7) Lancaster (Brandywine?) (440 to 400 feet). At present there are few who recognize as many erosion surfaces. As stated above, the Schooley and the Kittatinny peneplanes are generally believed to be a single erosion surface. Further, this region furnishes little evidence for the Mine Ridge, Honeybrook, and Sunbury. They are believed to be merely local features developed in other regions.

Streams *

The Lehigh River and tributary streams drain almost all of Lehigh County. The northwestern portion is drained by Ontelaunee Creek and its tributaries and the southwestern corner by the tributaries of Perkiomen Creek. Both of these creeks empty into the Schuylkill

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[11] Barrell, Joseph, Geol. Soc. of Amer. Bull., vol. 24, pp. 688-696, 1913.

[12] Barrell, Joseph, Amer. Jour. of Sci., 4th ser., vol. 49, pp. 227-258, 327-362, 407-428, 1920.

[13] Knopf, Eleanora B., Correlation of residual erosion surfaces in the eastern Appalachian highlands: Geol. Soc. Am. Bull., vol. 35, pp. 633-668, 1924.

* Much of the following matter has been taken directly or abstracted from an exhaustive investigation of the water resources of the State in 1916-1920 by the Water Supply Commission of Pennsylvania and published in 10 parts (see Bibliography).

River. Practically the entire area is well drained, although there are some localities within the limestone regions where there is no surface run-off. The water there flows underground in solution cavities. There are a few small swampy areas in the slate regions, especially in the northeastern part of the county where the glacial deposits are especially prominent.

The streams of Lehigh County have been of great value as sources of water power and municipal water supply. Gordon's Gazetteer (1832) states that "there are 46 grist mills, 28 sawmills, 5 fulling mills, 6 clover mills, 2 oil mills * * * in the County." (pls. 4 and 5.) Numerous others were built in later years. Most of these mills have long since been discontinued.

LEHIGH RIVER

The Lehigh River, rising in the Pocono Plateau of Wayne County, is about 100 miles long. It receives the drainage of almost all of Lehigh County. In its upper course, above the Lehigh Gap, it is a rapid stream with high bordering hills, but in its course along and through Lehigh County it has a moderate gradient. From Slatington to Allentown, a distance of 17 miles, the river descends 113 feet, or 6.65 feet per mile. From Allentown to Easton, 16.5 miles, it descends 68 feet, or 4.12 feet per mile.

As it flows through the slate region to Northampton it has a rocky bed in many places. Thence to Easton it passes through limestone and has a deep fill of alluvial matter. A number of alluvial islands are present below Northampton. These islands are mainly covered with trees of considerable size, furnishing evidence of their age, although at times of high water the islands do undergo some modification by erosion and deposition. Small bungalows built on some of these islands can not be used permanently owing to overflow at times of high water.

At Bethlehem a thickness of forty feet of alluvium in the river channel indicates an over-deepening at one time. Part of the fill consists of very coarse material with boulders as much as two feet in diameter. It is possible that the Bethlehem portion of the county was warped upwards while the thick ice sheet in the Pen Argyl district, Northampton County, depressed that section. When the ice melted the former conditions were restored. As the Bethlehem area sank to its normal elevation, the deepened river channel was filled. In Lehigh County, Jordan Creek has similarly a fill of more than 62 feet of alluvium. It is hoped that more data of this kind can be secured; then more positive explanations can be offered.

Eight dams have been constructed across the Lehigh River between the Lehigh Gap and Easton in order to effect navigation by the canal boats that transported anthracite from the coal regions to Philadelphia and towns between for over 100 years. The boats navigated the open river in places but in other places the canal dug beside the river. At present the canal is used only to furnish a small amount of water power at several places.

The Lehigh River receives some drainage from the anthracite districts and the black silt along the banks contains coal that has been carried from the culm banks and washeries of the coal mines. One can easily recognize coal particles in many places and occasionally, as far down as Bethlehem, thin streaks or small pockets of almost pure coal can be found.

A recent report[1] based on a special survey of the rivers of Pennsylvania, describes the fine-coal dredging operations along the Lehigh River. Three of these lie partly within Lehigh County. They are confined to the region above the Lehigh Coal & Navigation Company dams at Lehigh Gap, Three Mile Dam below Walnutport and the Treichler Dam at Laurys Station. The dredgers pay a royalty of fifteen cents per ton to the Navigation Company. The coal, when separated from the sand by screens and tables, is of good quality. The quantity obtainable varies with the seasons. Each flood brings down new supplies.

The Lehigh River throughout most of Lehigh County is in early maturity. (Plates 6 and 7.) Flood plains of considerable width are developed on one or both sides at many points. On these flat lands bordering the streams many residences and establishments have been built but the major portions of the river towns are on the higher ground. Railroads and highways follow well developed flood plains on both sides of the river across the county. In the construction of the railroad lines and highways it was necessary to remove considerable rock in some places, but not an excessive amount.

Minor Streams of Lehigh County

A. Tributaries of Lehigh River, with drainage area in square miles

Trout Creek	19.6
Little Trout Creek	4.9
Rockdale Creek	1.7
Fells Creek	3.3
Spring Creek	2.8
Coplay Creek	19.8
Little Lehigh Creek	187.6
Toad Creek	8.0
Schaefer Run	24.3
Breinig Run	1.3
Iron Run	11.3
Swabian Creek	12.4
Cedar Creek	14.8
Little Cedar Creek	4.8
Jordan Creek	81.0
Switzer Creek	6.4
Lyon Creek	12.3
Mill Creek	9.6
Hasson Creek	7.9
Monocacy Creek	49.6
Saucon Creek	58.2

B. Tributaries of Schuylkill River

Ontelaunee Creek	28.3
Kistler Creek	12.5
Hosensack Creek	18.2
Indian Creek	4.5

Trout Creek (Washington Township). The greater portion of Washington Township and part of Heidelberg is drained by Trout Creek and its principal tributary, Little Trout Creek. The headwaters are mainly along the lower slopes of Kittatinny (Blue) Mountain where numerous springs emerge. The valleys of the creek and tributaries are shallow in the upper portion, but in the vicinity of Slatington high cliffs border the stream. Water from the stream has been used for domestic purposes. In the early days water power was used for grist and saw mills. In the 1876 Atlas five mills are located. Others were built at an earlier date.

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[1] Comprehensive Studies and Analyses, Coal and Sand and Gravel Dredging Industries, Department of Forests and Waters of the Commonwealth of Pennsylvania, 173 pp., 1936.

Rockdale, Fells, and Spring Creeks. Three short parallel streams in North Whitehall Township, Rockdale, Fells, and Spring Creeks have cut steep-sided trenches in the Martinsburg slates as they flow eastward to empty into the Lehigh River. The water of Spring Creek furnishes part of the supply of the Clear Springs Water Company.

Coplay Creek. The change in topographic characteristics between the slate and limestone areas is well exhibited in the valley of Coplay Creek. The upper portion of the stream has cut its fairly steep-sided valley in the slates, whereas the lower portion flowing through limestones has cut a wide-open shallow valley. One of the earliest grist mills in the county was built along the creek a short distance below the Egypt church by Jacob Kohler in 1755. At least three other mills were built at different points farther upstream.

Little Lehigh Creek. The larger portion of the limestone valley between South Mountain and the slate belt is drained by Little Lehigh Creek and its tributaries. It drains a larger area than any of the other creeks of the county. Portions of the limestone belt through which the creek flows are without surface run-off streams, due to the abundant solution sinkholes and underground drainage channels. Undoubtedly some of the water that finds its way underground so readily does enter the creek eventually as springs, some of which are of large capacity. Cedar Creek, one branch of which receives the flow of the Schantz Spring, the principal source of Allentown's water supply, is an example. This spring furnished sufficient water power for a grist mill only a few rods from its emergence. This spring has been thought to be the continuance of Sinking Run a short distance northeast of Fogelsville, shown on Rogers' 1858 map but not on recent maps.

Few tributaries of the creek head in the limestone area, but some start in the hills of crystalline rocks to the south and a few head in the slate belt.

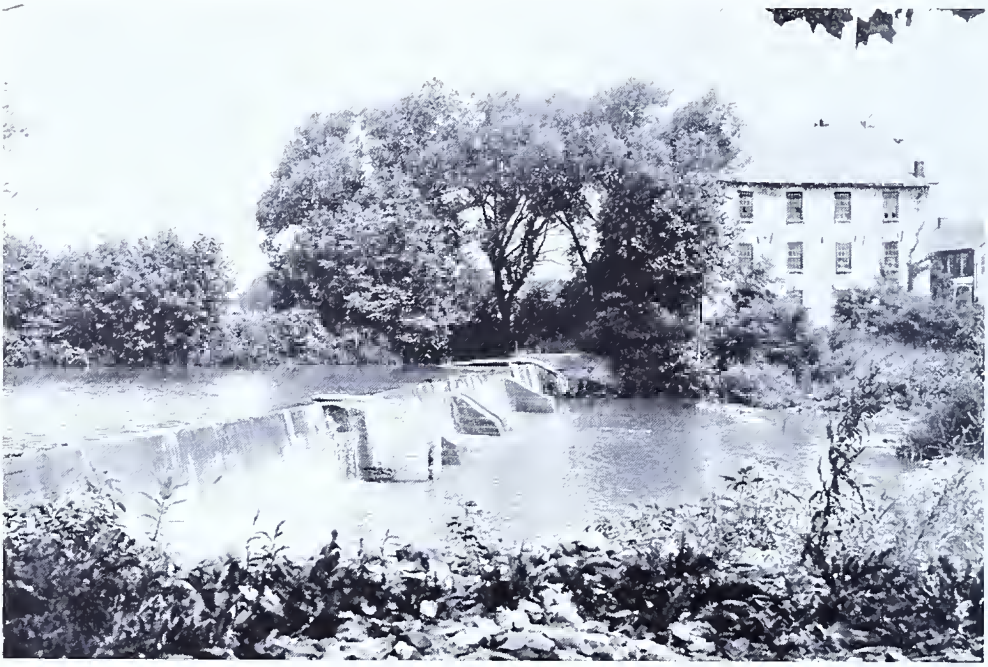
Particular attention is called to Schaefer Run, which has cut a notch between two slate hills. It evidently chose its course following the base-levelling of the slate hills and maintained its position during the subsequent uplifts of the region.

Another prominent feature of Little Lehigh Creek is the well-developed entrenched meanders along its lower course. These are indicative of a base level at about the present 400-foot elevation which persisted sufficiently long for the development of meanders. These became entrenched in the last pronounced uplift of this region. This portion of the creek is especially attractive and the highway along a portion of it affords the most scenic drive in the vicinity of Allentown. The trout ponds north of Western Salisbury Church have long been maintained. Several country homes have been built along this part of the stream.

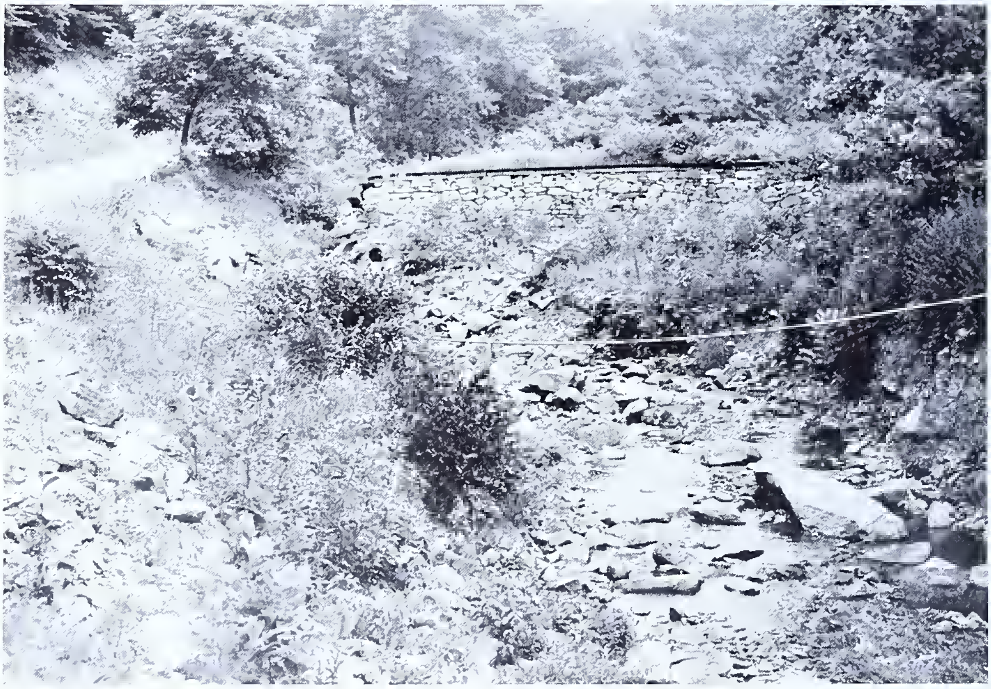
The 1876 Atlas of the county shows 16 mills along Little Lehigh Creek and tributaries, but according to historical records there were still others at an earlier date.

A. Kern's (Trucker's) saw mill on Trout Creek, Slatington. Built about 1845. Benjamin Franklin purchased lumber here in 1756 for building Fort Allen near present site of Weissport. Mill still in use.

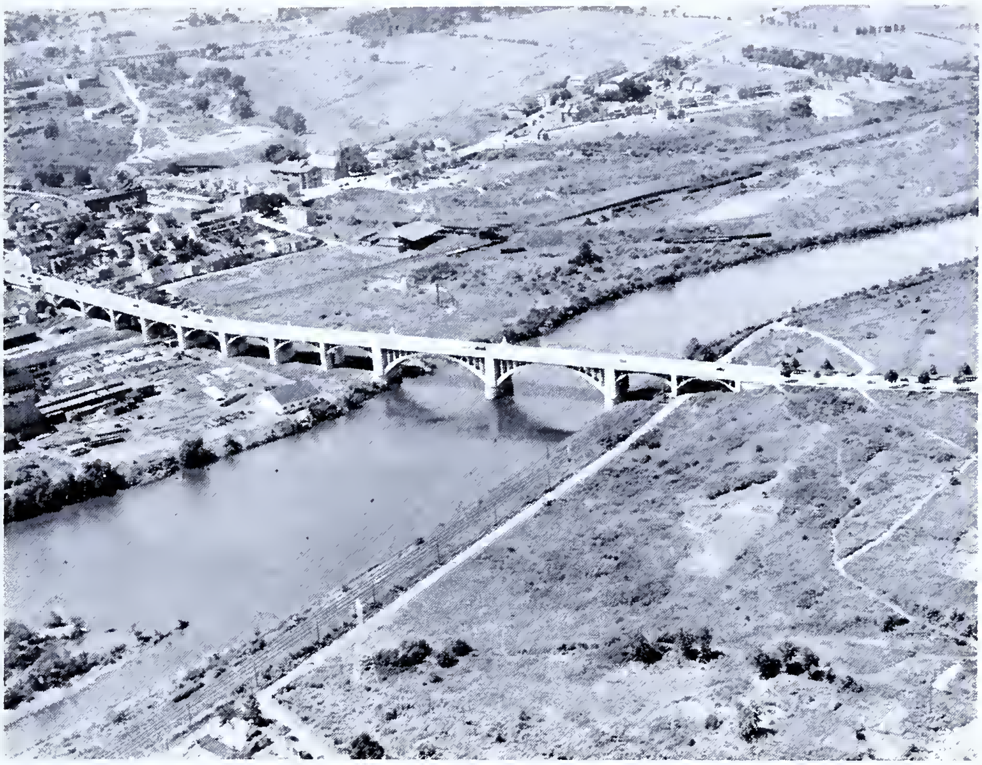
B. Snyder's grist mill on Switzer Creek two miles east of Lynnville, erected about 1770. Mill still in use but now operated by electric power.



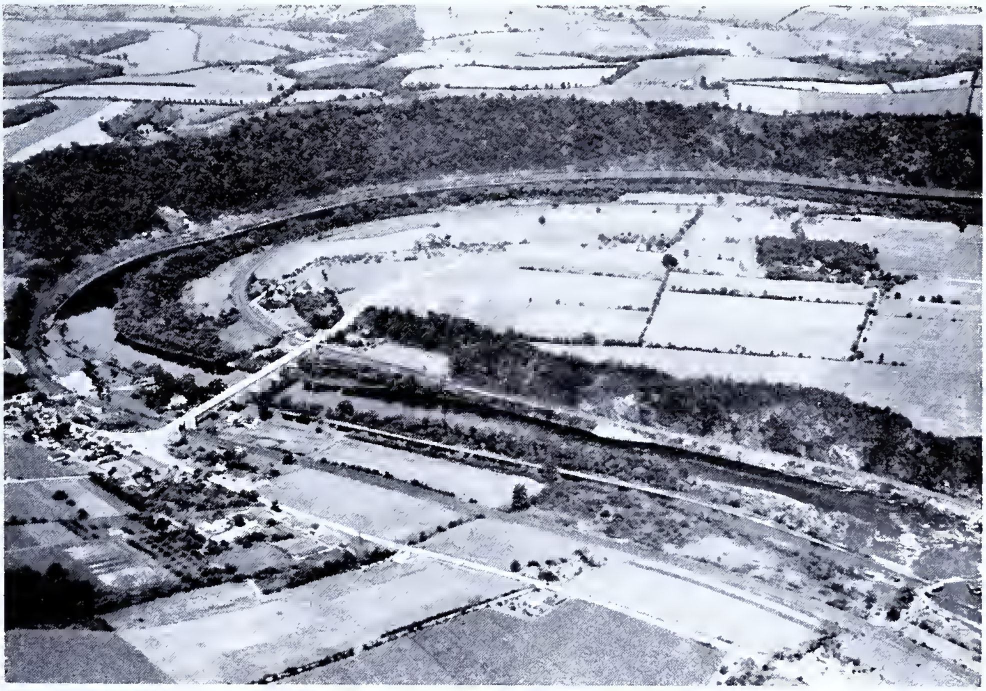
A. Wehr's dam and mill on Jordan Creek, half a mile east of Guthsville bridge. Mill built in 1862. One of the few concrete dams in the region.



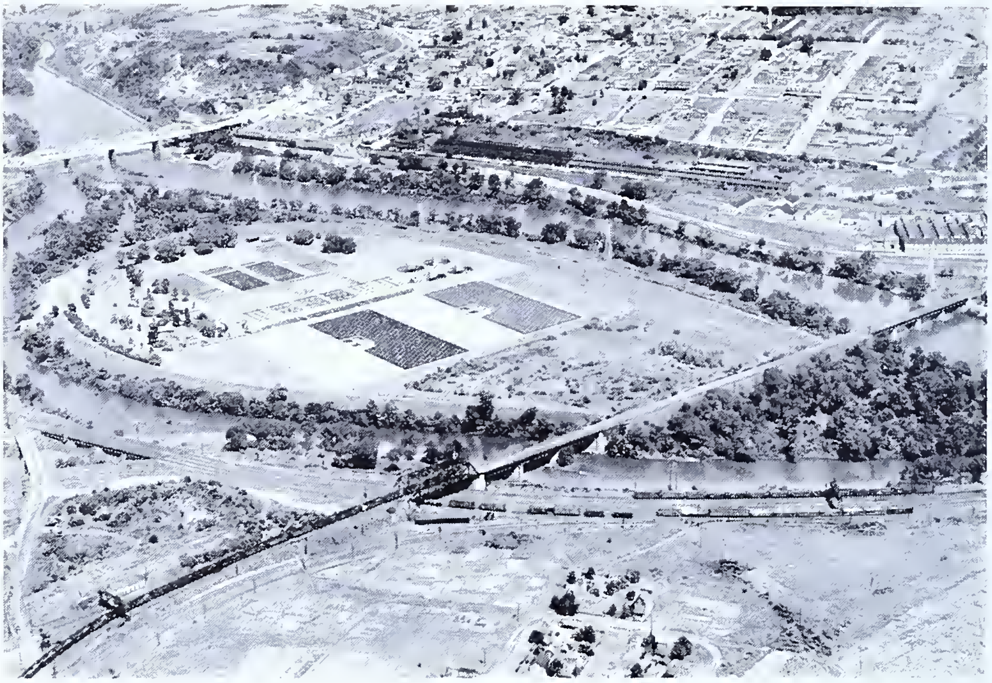
B. Broken dam on Indian Creek, Upper Milford Township. Blocks of gneiss in stream bed.



A. Lehigh River at Allentown, Tilghman Street bridge. North end of Adam Island in lower left corner. Bridge also spans adjoining low lands liable to floods.



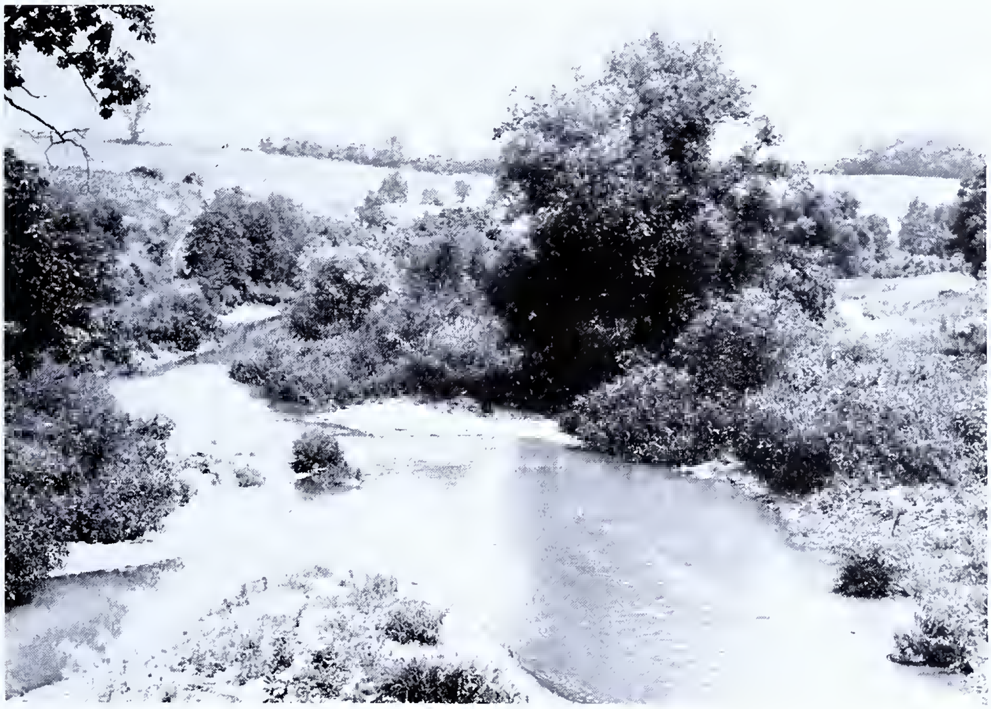
B. Meander in Lehigh River between Rockdale and Laurys Station. In center of view the river is flowing north. Village is Treichlers.



A. Jeter (Kline) Island, Lehigh River, Allentown, composed of alluvial materials. Note shape of island, narrowing at lower end. Sewage disposal plant on island.

B. Broken mill dam near Germansville. Old mill pond largely filled with silt and vegetable debris. Ground is marshy.

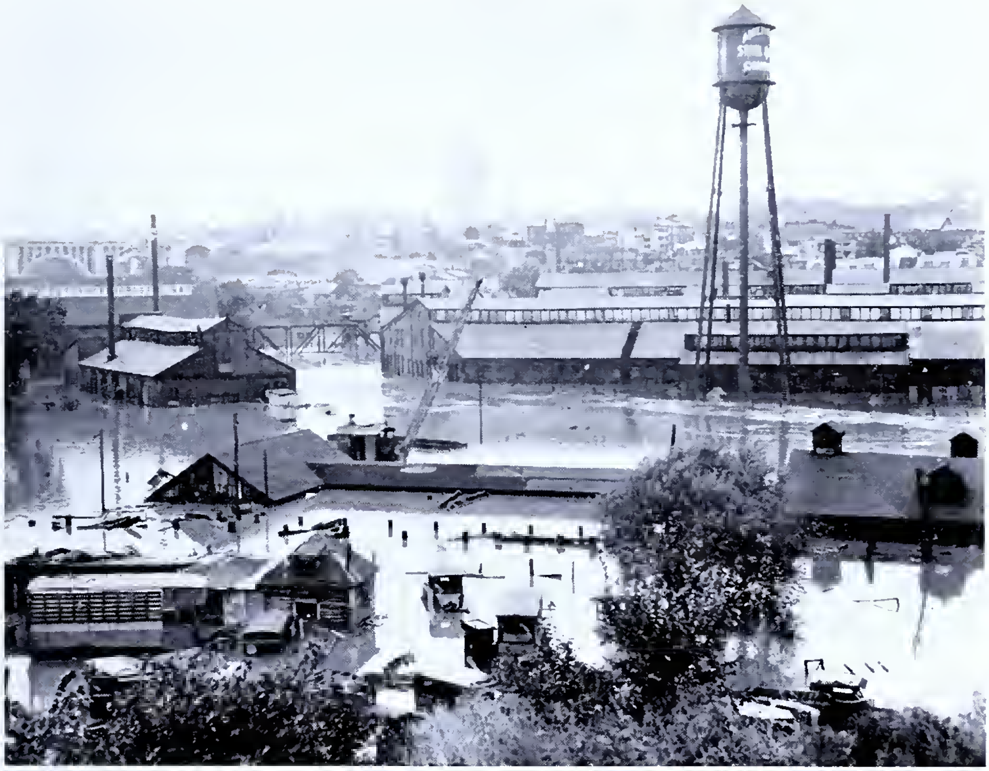
A. Jordan Creek. A small log dam provides a shallow ponding for boating and wading.



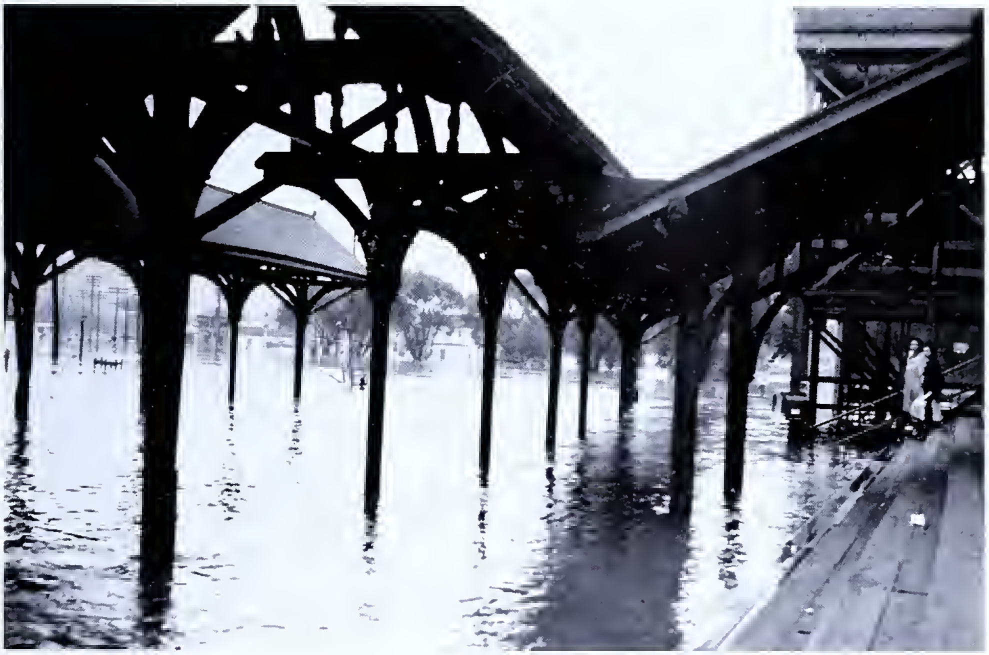
B. Jordan Creek. Shows silt deposits. The channel in places is being filled with soil washed from the cultivated fields.

A. Lyon Creek at Lyon Valley at site of mill dam. Typical stream of the slate region.

B. Jordan Creek, two miles south of Germansville. Site of former dam. Fence posts are on far bank.

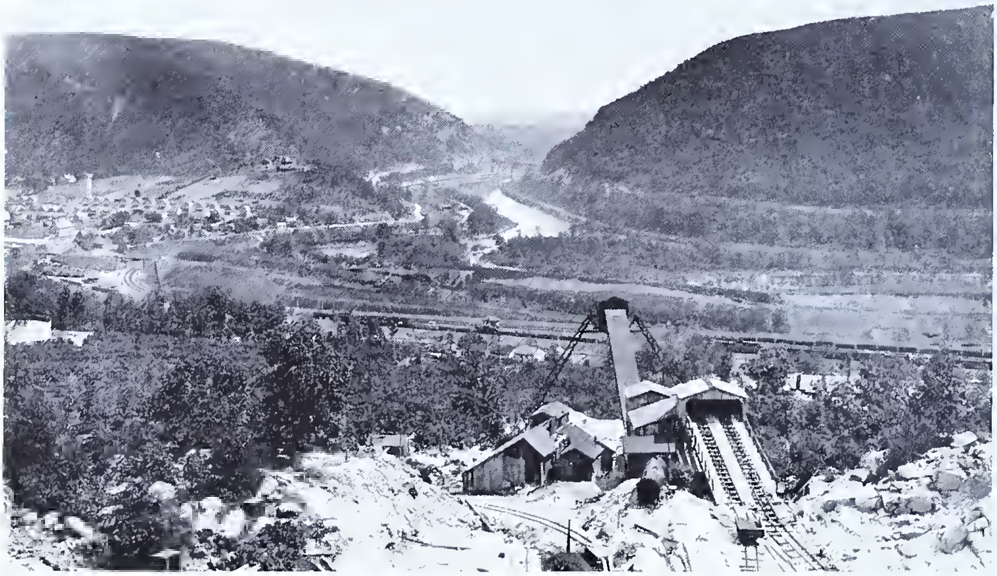


A. Little Lehigh Creek near the junction with the Lehigh River.



B. Lehigh Valley R. R. station with all tracks under water. Flood of Aug. 24, 1933, at Allentown.

A. Lehigh Gap from south, looking north.



B. Lehigh Gap from north side, looking south.

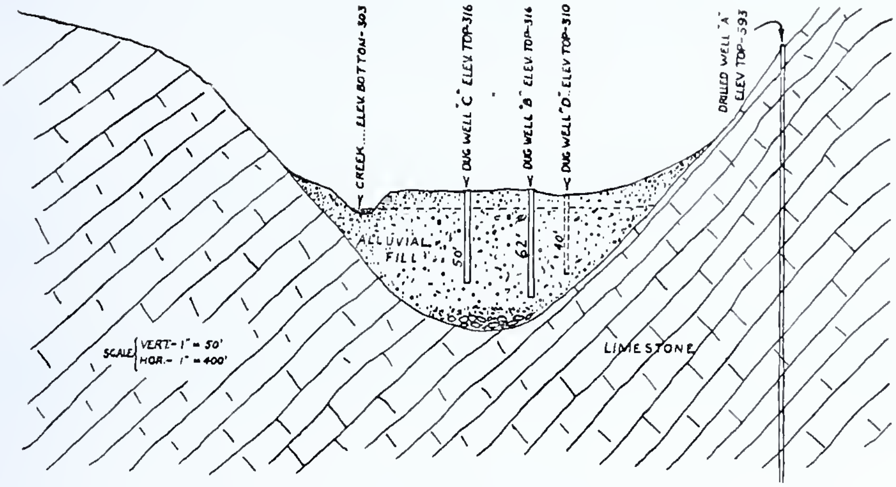

CREEK.....ELEV BOTTOM-303
DUG WELL "C" ELEV TOP-316
DUG WELL "B" ELEV TOP-316
DUG WELL "D" ELEV TOP-310
DRILLED WELL "A" ELEV TOP-393
ALLUVIAL FILL
50'
62'
40'
LIMESTONE
SCALE VERT.- 1" = 50'
HOR.- 1" = 400'

Figure 5. Cross section of Jordan Creek valley near plant of Trojan Powder Co. showing alluvial fill.

Trout Creek (Salisbury Township). A small stream, Trout Creek, which drains the Farmington region, is fed by a few substantial springs. At least two mills have been operated by its flow.

Jordan Creek. Jordan Creek (pls. 8 and 9), which enters Little Lehigh Creek close to its junction with the Lehigh River, in many respects is the most important minor stream of the county. Rising near the base of Kittatinny (Blue) Mountain it and its tributaries have dissected the slate region in an intricate fashion and have produced the most irregular topographic features of the county. Where it enters the limestone belt at Kernsville, the steep-sided valley changes to a broad open valley for several miles, except where bordered on the right by the slate of Huckleberry Ridge. Still farther down it shows entrenched meanders in the limestones similar to those of Little Lehigh Creek described above.

Jordan Creek always carries surface water in the slate belt, but frequently becomes dry in the limestone region. South of the Trojan Powder Company's plant, the channel has a fill of more than 62 feet of alluvial material (fig. 5), through which the water flows eastward even when the surface stream has disappeared. This over-deepening of the stream channel seems to have been brought about by elevation of the region when the nearby region to the northeast was covered by ice. With the close of the Glacial Period the region sank and the over-deepened portion was filled to its present condition by alluvial sand, gravel, and clay. The drying-up of the creek in a part of its course during dry summers has caused considerable distress to owners of summer cottages here and also to the fishermen.

Large springs, particularly Helfrich's Spring, which never goes dry, furnish water to the lower part of the creek.

The 1876 Atlas shows seven grist mills along Jordan Creek. Some of the textile mills and other manufacturing establishments have obtained power from the stream.

Monocacy Creek. For slightly more than one mile the eastern boundary of Lehigh County is Monocacy Creek. Only a small part of the county is drained by this stream and one small tributary.

Saucon Creek. Saucon Creek and its tributaries are almost entirely confined to the limestone areas of Saucon Valley. Most of the tributaries head in the gneiss hills on either side of the valley. The stream wanders a bit in the comparatively flat-bottomed valley with low slopes on either side. Until recently the valley was almost entirely agricultural. Mining of iron and zinc ores formerly was extensive. Now the valley is the site of many beautiful country homes.

Many mills have been built along this stream. Heller (History of Lehigh County, 1914) lists 11 mills and the Atlas of Lehigh County (1876) locates 14 mills in the Lehigh County portion of Saucon Creek and its tributaries.

TRIBUTARIES OF THE SCHUYLKILL RIVER

Ontelaunee Creek. Most of Lynn Township is drained by Ontelaunee Creek, which is in the slate belt and receives the drainage from Kittatinny (Blue) Mountain on the north and Shochary Ridge on the south. It flows through an open valley with well-developed flood plains, but a short distance on either side are high steep slopes. The channel is sinuous, with small meanders in places. The stream is at or near a temporary base level. The Ontelaunee flows into Maiden Creek and thence into the Schuylkill River.

Several mills rather famous in the early settlement of the region were located along the stream. Grist mills, sawmills, tanneries, distilleries, and textile mills derived power from this source. Eight mills have been located, but there probably were others.

Kistler Creek. On the south side of Shochary Ridge is the small westward-flowing Kistler Creek which unites with the Ontelaunee a short distance west of the county border. It drains a region of sandstones and shales of the Martinsburg formation into which narrow steep-sided valleys have been intricately cut. At least one mill has been built along the stream.

Hosensack Creek. Hosensack Creek with its chief tributary, Indian Creek, drains the southwest portions of Upper and Lower Milford townships. A short distance beyond the boundaries of the county it joins Perkiomen Creek, which is one of the principal tributaries of the Schuylkill River.

Industrial mills at one time or another have obtained power from the Hosensack and its tributaries. Ten mills are located in the 1876 Atlas of the county, but one writer states that ''More than twenty mills of different kinds have been operated by the Hosensack Creek and its tributaries, showing its appreciation by the settlers and its value to the community'' (History of Lehigh County, 1914). Most of them were grist and sawmills, but oil mills, powder mills, and a stave factory seem also to have received power from the stream.

The upper portion of Hosensack Creek follows closely the division line between the pre-Cambrian crystalline rocks and the Triassic red shales and sandstones. Here the valley is narrow with steep slopes. In the Triassic strata farther down it has developed a broad, open valley.

The major portion of Indian Creek flows through the pre-Cambrian gneisses. The valley is narrow with steep slopes. Near the village of Powder Valley the valley is especially attractive.

Perkiomen Creek. In the vicinity of Sigmund, Perkiomen Creek flows in a horseshoe curve through Lehigh County, entering from and returning to Berks County. Most of its valley is cut in the pre-Cambrian crystalline rocks. At least one mill has been operated in Lehigh County by water power from this stream.

Floods

There are records of several serious floods in the region. (Plate 10.) In several places high-water marks on buildings have been carefully measured.

Since 1888 the U. S. Geological Survey has been engaged in accurate measurements of the principal streams of the United States and the results have been published in annual Water-Supply Papers, in Bulletins, Professional Papers, Monographs and Annual Reports. In recent years the Division of Hydrography of the Pennsylvania Department of Forests and Waters has cooperated in this work. An annual bulletin of Stream Flow Records is issued and in addition in 1916-1917 an elaborate Water Resources Inventory Report was published by the State.

Of pertinent value to this region are the stream-gage data obtained at Bethlehem on the Lehigh River. Records are available in U. S. Geological Survey publications from September 1902 to February 1905, April 1909 to December 1913, October 1918 to September 1921, and October 1928 to September 1937. The Pennsylvania Department of Forests and Waters has published these records from September 1902 to February 1905 and April 1909 to date.

A record of floods has also been compiled. A gage height of fifteen feet usually results in a flood of sufficient magnitude to effect some damage. Therefore, the table lists all known floods in which such a height was attained.

Since the zero or datum plane is selected somewhat arbitrarily, the elevations above sea level are important. At Bethlehem the datum plane before 1909 was 213.45 feet above sea level; from 1909 to 1928 it was 210.64 feet and since 1928 it is 208.50 feet above sea level. These variations in datum plane are mainly due to the locations being moved either up or down stream. In every case a datum plane has been selected that is a foot or two below the lowest water known to have been reached even in the most disastrous droughts. The figures given are within close limits of what would have been obtained if the gage locations and gage zeros had remained constant during the entire time.

Major floods of the Lehigh River
(gage heights exceeding 15 feet)
Height of gage in feet at Bethlehem

Date	
1739	?
1747, Feb. 28	?
1777, Oct. 27	
1786, Oct. 4	18
1839, Jan. 26	16
1841, Jan. 8	23
1862, June 5	23.3
1869, Oct. 4	23
1894, May 21	17
1901, Dec. 15-16	17.5
1902, Feb. 28	25.9
1915, Feb. 26	16.8±
1924, Oct. 1	16.2
1926, Nov. 17	16.5
1933, Aug. 24-25	20.8
1935, July 10	20.7
1936, Mar. 12	19.0

The maximum measured height of the Lehigh River at Bethlehem was 25.9 feet on February 28, 1902 with a discharge of 92,000 second-feet. The minimum stage known was 1.33 feet on October 15, 1910 with a discharge of 160 second-feet.

It will be noted that floods have occurred in almost every month of the year. Although not borne out by the floods listed above, high-water occurs more frequently in the winter months, December to March. Practically all winter floods are caused by a combination of heavy rainfall and rapid melting of snow and ice over the drainage areas. At times ice jams have greatly increased the height of the water. Some high-water periods are explained by heavy, widespread spring and fall rains. The late summer floods have occurred when a West Indian hurricane coming up the Atlantic Coast has passed slowly over the region with excessively heavy precipitation for several days in succession.

The floods of the region are generally due to the Lehigh River, whose headwaters drain a region with many steep slopes and consequently a rapid run-off. Heavy rainfall in Carbon and Monroe counties or sudden melting of deep snow sends a great volume into the stream above Lehigh Gap. The water in the river backs up into the lower portions of the tributary streams or acts as a barrier to keep the creek waters from entering the river. At times the amount of damage is as great along these tributaries as in the major stream. At Allentown the water backs up both the Jordan and Little Lehigh creeks and at Bethlehem the Monocacy Creek. Residences and small industrial establishments in the low ground along these streams have suffered severely from floods.

In the local histories and newspapers there are accounts of disastrous floods during the early history of the region, but with few exact figures. During the 200 years since the settlement of the region there has been much destruction of property and some loss of human life. Residences, factories, railroads, and highways within the danger zone are bound to suffer considerable property damage whenever the streams rise to flood stage. The destruction of bridges was greater in the early days when all were of poorer grade than at present. In the 1841 flood all the Lehigh River bridges, which were entirely wooden, from Mauch Chunk to Easton were destroyed. The limitations of space forbid the description of the individual floods.

The damage done by a single flood is usually exaggerated at the time by the local press and by residents. It is practically impossible ever to determine the exact figures. In the February 28, 1902 flood it was estimated (Water Resources Inventory Report, Pt. VIII, 1917) that the following towns suffered the following approximate total monetary losses:

Allentown	$394,349	Coplay	$1,400
Bethlehem	64,360	Laurys	6,450
Catasauqua	23,276	Slatington	1,100
Cementon	2,000		

Each successive flood is apt to result in increased losses owing to the increasing value of the structures in the flooded areas. The tracks of the Lehigh Valley and the Central of New Jersey railroads have been covered with water to the extent that train service was halted for considerable time.

At various times there has been agitation for the institution of some effective flood control. Plans have been formulated, but as yet money has not been appropriated for the purpose. Under the auspices of the Works Progress Administration and the supervision of the U. S. Engineer Office of the War Department a detailed topographic survey has been made of the channel and flood plain of the Lehigh River between Easton and Laurys. This work was completed in 1937 in a series of 47 charts and stream profiles.

Evolution of the Drainage System

The development of the present drainage system of Lehigh County is linked up naturally with the evolution of the streams of the entire eastern portion of the United States. A full discussion leads one far afield and obviously does not properly constitute a part of this volume. It is highly theoretical in the main and probably always will be.

There is little disagreement among geologists regarding the existence of northwestward flowing streams during the Paleozoic era, by which sediments from the ancient continents were carried into the great interior sea. Following the Appalachian revolution the drainage direction was reversed. The Atlantic Coastal Plain is composed of the materials removed from the uplifted and folded regions lying to the northwest and west.

The present drainage system is believed to date from the uplift following Schooley peneplanation, or, according to Barrell and Johnson, from the elevation following the deposition of Coastal Plain sediments on top of the Schooley peneplane. Most geologists agree that the major streams following this uplift flowed to the southeast. The existing major streams of eastern Pennsylvania now have a general southeasterly course, but in certain portions of their courses turn sharply to the northeast or southwest, parallel to the structures of the hard rock ridges of the folded mountains. These abrupt changes in course indicate plainly that there have been adjustments in the original streams. Much speculation as to what has been their history has resulted. Davis (1889), Walter (1895), Williams (1902), Johnson (1931), Ver Steeg (1930), and Itter (1936-1938) (see Bibliography) are the principal writers on this problem. Most of them believe that the southeasterly-flowing portions of the existing streams are original features, and that adjustments to geologic structures have been accomplished by stream piracy and dismemberment of old streams. The presence of shale and limestone valleys between the resistant rock ridges has especially favored such processes. The changes which affect the streams of Lehigh County only can be considered here.

Williams[1] offered an explanation of the change of course of the Lehigh River at Allentown. He believed that originally the Lehigh from Lehigh Gap flowed south or southeast until the vicinity of Allentown where it turned to the southwest, passed through Leibert's Gap near Emmaus and continued to the Perkiomen Valley. He thought that a westward-flowing tributary existed along the north side of South Mountain from Freemansburg or beyond and joined the Lehigh in the Allentown region. Monocacy Creek is thought to have been a tributary of this stream and instead of its present course, it turned to the southwest in the north part of Bethlehem and crossed the present highest portion of West Bethlehem. This filled valley has been partially located by well borings. He supposed that a tributary of the Delaware River flowing past Glendon pushed its head westward until eventually it captured the Lehigh River at Allentown. This theory is worthy of examination, although it has not generally been accepted.

A deep deposit of sand and gravel a short distance east of the Lehigh & New England Railroad in East Allentown and a similar deposit along Prospect Avenue in West Bethlehem that is known to be 138 feet in depth, give some indication of a filled valley that may have been cut by the Lehigh River before the ice sheet invaded the region. Instead of the present course south of the East Allentown hill the river may have flowed on the north side in an almost east course from a short distance south of the present site of Fullerton to about the present mouth of Monocacy Creek.

In several other places in Lehigh County there are evidences of changes in some of the minor streams. It is a fascinating subject for investigation and should receive further consideration. Well borings and perhaps geophysical data may furnish additional information.

Water Gaps and Wind Gaps

A water gap is a short, narrow, steep-sided pass or gorge by which a stream cuts through a hard, resistant rock ridge. A wind gap is an abandoned water gap or notch in a ridge cut by a stream that was later diverted or captured. Examples of wind and water gaps are numerous throughout the folded Appalachians of Pennsylvania.

In Lehigh County the most prominent are the Lehigh water gap (pl. 11), through which Lehigh River flows, and the Lehigh Furnace wind gap, both cut in the resistant sandstones and conglomerates of Kittatinny (Blue) Mountain. In the south part of the county Leiberts (Leipert) Creek cuts through South Mountain north of Vera Cruz, and Indian Creek through another ridge of crystalline rocks, to form two minor water gaps. Several notches in South Mountain might appropriately be designated as wind gaps. Different explanations, some highly fantastic, have been proposed to account for these phenomena.

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[1] Williams, Jr., E. H., Bull. Geol. Soc. of Amer., vol. 5, pp. 281-296, 1894; Proc. and Coll. of Wyoming Hist. and Geol. Soc., vol. 7, pp. 21-28, 1902.

Lehigh Water Gap. The scenic and economic features of the Lehigh Gap have been commented upon by almost all the early visitors in the region. A typical quotation is given.

> *Die Lecha Wasser-Kaft*, i.e., the *Lehigh Water Gap*, in the Kittatiny, or Blue Mountain, the dividing line between Carbon County and that of Lehigh and Northampton, is so named from the river Lehigh, which steals its way through the Gap, prominently walled on both sides, forms a sublime object of admiration, and presents to the observant spectator, one of the most picturesque prospects in east Pennsylvania. At almost every season of the year, the diversified defile is exceedingly attractive. The writer visited this place in September, 1844. In ascending the eastern bank some hundred feet, the scene heightens in grandeur, and the stream—the beautiful, yet curling, rippled waters of the Lehigh River, add much, nay every thing, to make it impressive beyond oblivion. Though it is seemingly a rugged stream *here*, yet as you follow it in its course, through a fertile region of country, receiving tributaries of different sizes, until itself is a considerable river, before it reaches its silvery recipient, the Delaware. It is in all its ways, as well as at the *Gap*, where it rolls majestically over a rupic bed, and reflecting a sombre shade of the impending mountains, a grand stream.
>
> To return to the *Gap*. The eastern bank is bordered for the distance of about a mile by craggy cliffs, towering to an amazing height, and of forms the most *bizarre*. Between which wall of rocks and the river the road winds along. Hastening to leave these black abodes, which seem to afford shelter to none but the ravenous beasts of the forest, the Lehigh appears eagerly moving on towards the fertile low lands, which succeed in view, on the eastern bank.
>
> Ascending the eastern height, the traveler is amply rewarded for the exertion of climbing from rock to rock, in scaling the pine-covered side of the mountain, by the rich and extensive prospect which the eye then commands. At his feet roll the waters of the majestic stream—on the opposite side is a towering ridge, near the summit of which appears, right opposite, emerging from the surrounding woods, a lonely pile of rocks, whimsically called, "*Die Teufel's Kanzel*," i.e., "*The Devil's Pulpit*," which indignantly suffers but a few blasted pines to shade its sullen brow. At a distance an extensive country, variegated with woods and farms, watered by the meandering Lehigh, and ridge retiring behind ridge, till lost in the faint tints of the horizon, all bursts upon the sight, and fill the mind with sublime ideas of the greatness of the Creator. The shattered rocks, thrown together in wild confusion, and the strata of rounded stones, which are to be met with in passing through the Gap, have given rise to the supposition that the Lehigh, being obstructed in its course by the Blue Mountain, was formerly dammed up into a lake, which at length bursting the barrier, formed the chasm now called the *Lehigh Gap*. The learned have not agreed, as yet, in the decision of this mooted point. (Rupp, 1845, pp. 113-114.)

To account for the origin of water gaps it is not necessary to assume that Lake Ontario or some other lake once extended to Kittatinny (Blue) Mountain and suddenly burst the barrier, as dams collapse under abnormal water pressure; nor to assume the breaking of a mountain ridge by a great earthquake or the formation of the gap at the time of Creation. With the modern conception of geologic time measured by hundreds of millions of years rather than by hundreds or thousands, we realize the great effects produced by slowly-acting but long-continued natural forces.

The water gaps are solely the work of the rivers themselves. Whether there was an original depression or a zone of weakened rocks that determined the place where the Lehigh River crosses Kittatinny (Blue) Mountain cannot now be demonstrated. Some geologists think that there is evidence of discordance between the strata on the two sides of the river at Lehigh Gap explained by structural differences. This lack of alignment, however, is slight and is believed to be due to a very minor change in direction of strike produced in the original folding. Elsewhere in the Appalachians similar phenomena have led some geologists to attribute the position of water gaps generally to those places where there are structural changes, either cross folds or faults.

The Lehigh River is believed to have taken its present course across the mountain when the whole region was base-leveled to form the Schooley peneplane. A gradual uplift gave the stream renewed cutting power and regardless of the hardness of the strata the rolling of cobbles and sand by the running water cut the bedrocks as by a file. The cutting amounts to more than 1,000 feet in that the river now has an elevation of 393 feet above sea level and the top of the mountain ridge a short distance to the west is over 1,400 feet. Furthermore, the ridge has undoubtedly been lowered an indeterminate but probably small amount, and an unknown depth of alluvium in the stream channel increases the total amount of cutting.

When the Lehigh River started the cutting, it is probable that it was flowing over a featureless plain either of erosion, the newly formed Schooley peneplane, or of deposition according to Johnson.[1] We assume that this plain had a fairly gentle slope to the Atlantic Ocean, although absolute proof is lacking.

Barrell[2] in his studies in this region noted the change of slope in the profiles of both the Delaware and Lehigh gaps and suggested that they represented alternating periods of uplift and stability. He called the more gentle slopes "facets" and attempted to correlate their lower levels with the floors of local wind gaps. Barrell had not completed his investigations at the time of his death.

Ver Steeg[3] in his much more detailed investigations reaches different conclusions as shown in the following quotation:

> Barrell believed that the form of the wind and water gaps might give valuable evidence as to the nature of erosion cycles. He was of the opinion that the facets in their profiles are indicative of still stands of the land, during which peneplanation took place. The present writer believes that the facets are the result of unequal resistance of hard rock beds to erosion. Where there are alternating layers of hard and soft rock which stand at an angle sufficiently low, rock ledges produce facets. As a rule, the more resistant beds project into the gaps, whereas the softer beds weather down to gentler slopes. Where the beds stand at high angles, facets are absent.

Shale and limestones underlying great areas on both sides of Kittatinny (Blue) Mountain, being much less resistant to erosion, have been removed by tributary streams in much greater volume. To restore the region now composing Lehigh County to its pre-water gap condition, it is estimated that we would need to add an average of 300 feet over the South Mountain belt, 400 feet over the slate region and 800 feet over the limestone region. This is an average of about 477 feet for the entire county. These are regarded as the minimum figures. Expressed in tons, several hundred billion tons of rock has been carried from the area comprising Lehigh County by the Lehigh River since it began to cut the gap in Kittatinny (Blue) Mountain. Some of this material was carried away in solution and entered the Atlantic Ocean. The major portion was sand and silt carried in suspension or rolled along the bottom of the stream. Most of this material likewise was carried to the ocean, although some was dropped in the channel or on the flood plains of the lower course of the Lehigh or the Delaware Rivers.

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[1] Johnson, D., Stream Sculpture on the Atlantic Slope: 1931.

[2] Barrell, J.: Amer. Jour. Sci., 4th ser., vol. 49, pp. 227-258, 327-362, 407-428, 1920.

[3] Ver Steeg, K.: Annals, New York Acad. of Sci., vol. 32, pp. 87-220, 1930.

The lower, south slope of the mountain at Lehigh Gap is composed of Martinsburg shales dipping to the north. Owing to the heavy cover of talus they are not exposed in place on the Lehigh County side, but on the Northampton County side railroad and highway cuts present excellent exposures. The higher slopes and the crest are formed by the Tuscarora gray sandstones and conglomerates dipping to the north throughout Lehigh County so far as known. The north slope is formed by the prevailingly red sandstones and shales of the Bloomsburg and Clinton formations.

The economic importance of the Lehigh Water Gap deserves mention. Three railroads, one much-traveled highway, and a canal pass through it. Before the advent of railroads it was used by the early settlers, and still earlier by the Indians on their way to their favorite hunting grounds to the north of the mountain. The narrowness of the gap has made it necessary to remove considerable rock for these transportation lines, but this is insignificant in comparison with the work accomplished by the river.

Leiberts (Leiperts) Water Gap. The highway between Emmaus and Vera Cruz passes through a narrow water gap through South Mountain. Leiberts Creek, a tributary of Little Lehigh Creek, flows northward through the gap. The center of the gap is about 475 feet above sea level, the top of the mountain ridge to the west about 700 feet, and the one to the east 943 feet.

The gap is a large one to be cut by a small stream and furnishes some evidence in support of the view advanced by E. H. Williams, Jr., mentioned on a previous page. If the Lehigh River did flow southward through this notch to join the Perkiomen before the Ice Age the bulk of the cutting must be assigned to this larger stream. When and how the present northward-flowing stream replaced the supposed previous southward flow calls for considerable speculation.

Regardless of which stream cut Leiberts Gap, the location of the gap seems to have been determined by rock structure. There is evidence of faulting on both north and south slopes of South Mountain at this place in that the Hardyston sandstone is missing and limestone is in contact with the gneiss. An iron mine a short distance northwest of the gap and another one to the southeast were both in limestone, as evidenced by the rotten sericitic shales found in the mine dumps. These are typical of the metamorphosed impure limestones in which the valley type of limonite iron ores was formed.

A suggestion has been made that downward faulting has brought a narrow block of limestone below the present channel of Leiberts Creek and that limestone forms the basement throughout the gap. Attempts to secure well boring data to determine whether this is the case have been unsuccessful. The writer believes, however, that the notch has been cut down to its present level in gneiss by stream action from the original peneplaned crest of South Mountain. Faulting nearby undoubtedly shattered the crystalline rocks to such an extent that a stream could much more easily carve a channel here than where the rocks are less broken and thus exerted a controlling influence in the location of the gap.

This gap gives easy passage from the Great Valley to Saucon Valley and the highway through it is much used.

Indian Creek Water Gap. Indian Creek has cut a deep narrow water gap in a spur of South Mountain crystalline rocks at Powder Valley. The gap is over 200 feet deep and is utilized for a highway.

Wind Gaps of Kittatinny (Blue) Mountain

Wind gaps are gaps or notches in mountains, cut by streams which were later diverted to other places. They are common features in the Appalachians and elsewhere where adjustments of stream courses to geologic structures have taken place. The name suggests some connection with air currents and at times their origin has been erroneously attributed to the wind. They have received their name because occasionally surface winds are turned or directed by these gaps to such an extent that they are noted by the local residents.

Conditions are extremely favorable for stream diversion in this portion of the Appalachians and thus for the formation of wind gaps. The ridge of hard resistant rocks forming Kittatinny (Blue) Mountain is paralleled by a band of soft shales along the northern flank. Tributaries flowing over these soft shales have been able to push their heads backward until they encountered streams crossing the hard rocks of the mountain and cutting very slowly. Diversion of the stream has resulted.

The only prominent wind gap in Lehigh County is Lehigh Furnace Gap, although Ver Steeg (1930) has designated a minor gap near Bake Oven Knob as also a wind gap. In view of the fact that Ver Steeg has made such a thorough study of this region, his description * is quoted in its entirety. His comparison with Little Gap (Northampton-Carbon counties) is of interest.

Lehigh Furnace Gap

Lehigh Furnace Gap is located about four and one-half miles directly west of Lehigh Gap. Through it passes an unimproved road which connects with the concrete highway at Ashfield, Pennsylvania.

The sequence of formations and structure is in general like that at Lehigh Gap, four and one-half miles to the northeast. The beds of Shawangunk conglomerate appear to dip 25° to 30° to the northwest.

Lehigh Furnace Gap has an elevation of 1305 feet A. T., about 300 feet below the summit of the ridge, which attains an elevation of 1600 feet A. T. on the east side. The width of the notch is about one mile across the top and its bottom, which is broad and rounded, is approximately one-tenth as much. The gap stands about 600 feet above the level of the Harrisburg peneplane, which has an elevation of about 700 feet A. T. in the Great Valley to the south.

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* Ver Steeg, Karl, Wind Gaps and Water Gaps of the Northern Appalachians, their characteristics and significance: Annals N. Y. Acad. Sci., vol. XXXII, pp. 87-220, New York, 1930.

From a point about one mile directly south, the gap appears as a broad, rounded, shallow depression with slightly concave sides, the maximum angle of slope being but 12° on the west side and 9° on the east side. When seen from the town of Ashfield to the north of Blue Mountain, and directly in line with the gap, the slopes are the same as those obtained from the south.

The floor and sides of the notch are covered with a thick layer of rock debris. On the south side of the ridge, along the road, at a point about 100 feet below the bottom of the gap, a pit from which road material has been taken shows 15 feet of talus, soil and other weathered material, and no bed rock in sight. The Shawangunk conglomerate appears in places in great masses, and occasionally in boulder fields like the one in Little Gap but much smaller in extent. The sides of the gap have gentle slopes which are easily ascended, especially at the bottom where the surface seems nearly horizontal. They merge very gradually into the ridge crest by a continuously convex, broadly rounded curve. No ledges of rock outcrop on the sides, which appear to be graded and are everywhere covered by an accumulation of soil and angular boulders of the Shawangunk conglomerate. Although changes of slope or slight undulations are present in the profile of the notch, there is nothing that can be interpreted as a facet, either structural or due to peneplanation. It is probable that the irregularities in the profile are due to concealed rock ledges, since the low angle of dip of the beds at this place is favorable for their development.

The gentle slopes of the sides of the gap are due to the fact that the notch has been abandoned to weathering since the piracy converted it into a wind gap. The weathered materials and talus accumulations have collected on the slopes and the floor, because there is no stream constantly to deepen and widen it, thereby carrying away the debris which works its way down slope. Water gaps are characterized by steep, bold cliffs, numerous rock outcrops, and sides which meet the ridge crest and floor of the gap at sharper angles than in the case of the wind gaps. On the other hand, the wind gaps, long abandoned by the streams which once occupied them, have gentle slopes, few prominent rock outcrops and great accumulations of debris, which have gradually moved down slope covering the sides and the floor, producing the broadly rounded bottom profile so characteristic of them.

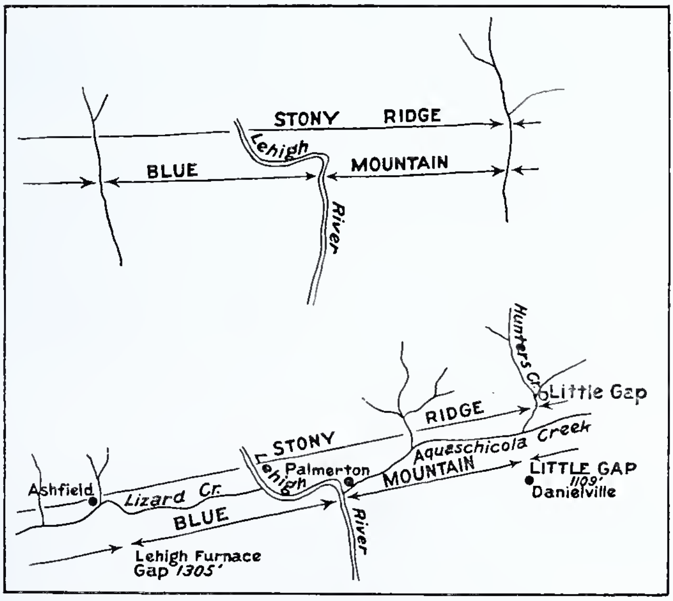

Figure 6. Sketches showing the drainage changes which took place in the vicinity of Lehigh Gap. Piracy by Lizard Creek has produced Lehigh Furnace Gap in Lehigh County and by Aquashicola Creek the Little Gap in Northampton County.

> The stream which flowed through Lehigh Furnace Gap prior to its capture (Fig. 6), was very probably a large branch of Trout Creek, a tributary to Lehigh River. Lizard Creek, a subsequent stream that had the advantage of working headward on weaker formations, beheaded the stream which was striving to cut its way down through the hard conglomerates and sandstone of which Blue Mountain consists. With Lehigh Water Gap the two wind gaps, Little Gap and Lehigh Furnace Gap, constitute a sort of unit. Both wind gaps were occupied by tributaries to the Lehigh River and both are about equally distant from the Lehigh Water Gap. But Little Gap is deeper than Lehigh Furnace Gap, the elevation of the former being 1109 feet A. T., whereas the latter is 1305 feet A. T. The stream in Lehigh Furnace Gap was probably the first to be beheaded, because Lizard Creek had a distance of but two miles to go from Lehigh River in order to complete the capture. On the other hand, Aquashicola Creek had to cover four miles before it could behead the stream flowing through Little Gap. We have in this case two wind gaps, occupied contemporaneously by two streams comparable in size, both tributaries to the same stream and nearly the same distance from it. If wind gap elevations are related to peneplanes, it is difficult to explain the difference in elevation of the two gaps. According to this theory Lehigh Furnace Gap at 1305 feet A. T. marks a peneplane surface at that elevation, and Little Gap at 1109 feet A. T., which is 196 feet lower, still another. It seems almost inevitable that Aquashicola Creek, fully as large or even larger than Lizard Creek, would have beheaded the stream flowing through Little Gap, at about the same time or shortly after the capture had taken place at Lehigh Furnace Gap. It is difficult to believe that the Little Gap stream survived through another complete cycle of erosion before beheading took place. Such a survival would imply that either Aquashicola Creek accomplished the piracy which produced Lehigh Furnace Gap, or that it was a small stream and had not yet worked headward sufficiently far to behead the Little Gap stream.

It should be noted that Aquashicola Creek and Little Gap lying east of the Lehigh River are beyond the confines of Lehigh County.

How much change has taken place in the Lehigh Furnace Gap since the steam originally present here was turned into Lizard Creek is not known, but it is not thought to be great.

A moot question that has aroused considerable discussion pertains to the correlation of wind gaps with old erosion surfaces (peneplanes). Barrell (1920), Hickok (1933), and Meyerhoff and Olmsted (1934 and 1936) hold to the view that the floors of wind gaps throughout the Appalachians can be correlated with each other in groups and that they are intimately related to the peneplane levels and are thus indicators of cyclic uplifts. Ver Steeg (1930, 1933, and 1935) on the other hand, as shown by the above quotation, argues strenuously against such relationship. The discussion of this question leads far afield and can not be treated except with consideration of many areas outside Lehigh County. Therefore it is regarded as proper to merely state the problem in this volume.

Caves, Sinks and Underground Drainage Systems

In the limestone areas of Lehigh County there are many subterranean openings into which surface drainage flows. Even a casual glance at the map shows the paucity of streams in the limestone regions as compared with the slate regions. Over considerable areas west of Allentown and in the Saucon Valley there is no surface run-off, all of the rain water not quickly evaporated or taken up by vegetation disappearing underground. Drainage systems with major and minor streams develop underground in a manner somewhat comparable to surface drainage patterns. As stated on a previous page some of these streams emerge as large springs.

Sink holes are common features in the fields of the limestone area. Into these sinks the farmers dump field stones and refuse of all kinds. Some report the enlargement of the sinks in spite of repeated efforts to fill them. One also hears of farm animals falling into underground cavities.

So numerous are these caverns that until recently nearly all the residents of the towns built on limestone disposed of their house sewage by dumping it into "wells" that extended down to some opening. Occasionally stoppage of these channels has necessitated the sinking of new holes, but in most cases this method of sewage disposal has been entirely satisfactory. In recent years most communities have constructed sewers, but by no means all the homes have changed their old method by connecting with them.

The cavernous character of the limestones is described in a brief article * by the writer which is here quoted.

> Several years ago, the writer discovered a strong current of cold air coming out of some crevices in a limestone quarry in East Allentown on hot summer days. The quarry is along the bank of the Lehigh River and only a short distance northeast of the Hamilton Street bridge. The limestone belongs to the Tomstown formation; overlying strata of the Allentown formation make the crest of the hill. The rocks are badly shattered by much folding and faulting. Although there are several openings in a wall of the quarry, the cold air emerges from only a few.
>
> During the past year the writer learned of another similar occurrence. On Club Avenue, which forms the boundary line between Bethlehem and Allentown, a hole was drilled about 100 feet in depth in order to drain the back lawn of a property. It was soon found that a strong blast of cold air came out of the well during the summer. The well has been visited numerous times and found to change from out-going to in-going air, dependent on the weather conditions. On a very cold day there is a strong in-going current although even in the winter on a mild day this may be reversed.
>
> Although the Lehigh Valley in this section contains several thousand feet of limestone, and numerous sink-holes can be seen in the fields, no caves of consequence have been found. The underlying rocks, however, have long been known to be cavernous. The common and almost universal method employed in the disposal of residence sewage in the towns located on these limestones until recently was by flushing it into these caverns. A hole or well was sunk near the building until some cavity was encountered. Seldom was it necessary to drill more than 50 or 75 feet. Rarely did these cavities become clogged, thus indicating an intricate network of openings that must exist in these rocks. Undoubtedly the complicated geologic structure of the district is largely responsible for the abundance of these cavities. Most of them must be of small diameter but connected with a great series of similar openings.
>
> The two occurrences of cold summer currents described above indicate a large supply of cold air that has in some manner been stored in these underground passages. Otherwise, the phenomena would be of short duration and would disappear long before the end of the summer.
>
> At present there is little basis for designating these caverns of the Lehigh Valley as "ice" or "freezing caverns" such as have been described from various parts of the world. Yet it is not improbable that ice might be encountered if it were possible to follow these narrow passages into the

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* Miller, Benjamin L., Breathing caverns of the Lehigh Valley: Proc. Pa. Acad. Sci., vol. XII, pp. 105-107, 1938.

hill. Many articles on this subject have been written * and various theories have been offered to explain the formation of the ice. Local residents have long claimed that the ice formed in summer and disappeared in the winter. Andrews substantiates this belief and offers plausible explanation. He claims that the air that enters the cavities in the winter is below the freezing point and as it emerges during the summer it freezes the percolating water that enters the caverns, especially near the surface.

Although it is not advisable to announce ice caverns in the Lehigh Valley we can say that there are concealed openings that draw in great quantities of cold air in the winter and expel it in the following summer. Perhaps these cold air currents may account for the unduly low temperatures of the waters of some wells and springs in the Valley.

There are no caves of importance in Lehigh County. None is listed in Caves of Pennsylvania by Ralph W. Stone. Nevertheless there are three small ones that many years ago received considerable attention.

Helfrich Cave. About 1½ miles north of Allentown, Jordan Creek makes a sharp meander to the north, looping around a prominent hill of limestone. On the east side is located Helfrich Spring, described under Springs. Part of the water comes out of a cavern at the base of the hill. In Gordon's Gazetteer (1832) is the following:

> There is a remarkable limestone cave in North Whitehall t-ship, within 2 or 3 ms. of Allentown, on the bank of the Jordan Creek, near which is a spring equally remarkable, called the Cavern spring. (p. 243.)

The cavern extends into the hill in a westerly direction as a single narrow passage approximately parrallel to the strike of the limestone strata. At one time a boardwalk was built and electric lights installed and visitors were conducted into the cavern to a distance of "several hundred feet." Admission was charged. The boards of the walk have decayed and access is considered dangerous.

At times of high water in Jordan Creek a large stream of water flows from the cave. This is due to part of the creek taking a short-cut through the hill instead of the longer passage around the hill.

Erdman Cave. Rupp (1845) in his description of Upper Saucon Township says, "Lately a cave has been discovered called 'Erdman's Cave.' It has been but partially explored. It is said there is a fine stream of water in it." (p. 138.) No other mention of the cave has been found, so that the location is unknown. The author's surmise is that it may be the small cave discovered in the limestone quarry at Limeport. This opening at present is small and insignificant. It may formerly have been larger, a portion having been removed in the quarry operations.

Sigmund Cave. Two large limestone quarries were once operated a short distance southwest of Sigmund to supply fluxing stone for the Hampton (Sigmund) Furnace. A nearby resident is authority that at one time a cave was discovered there that could be entered to a distance of 65 feet.

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* Browne, G. F., Ice-Caves of France and Switzerland, 315 pp., 1865.

Balch, E. S., Glaciers or Freezing Caverns, 337 pp., 1900. Contains an elaborate bibliography.

Andrews, M. O., The Sweden Valley Ice Mine and Its Explanation: Pop. Sci. Monthly, vol. 82, pp. 280-288, 1913.

Besides these caves, others have been found in the operation of limestone quarries or exposed in limestone bluffs. A small cave in the large Ziegenfuss limestone quarry in southwest Allentown yielded some very attractive specimens of aragonite and travertine. F. R. Faux has described this cave in Rocks and Minerals (Nov. 1935).

> About five years ago, workmen, at the Ziegenfuss Quarry, at Allentown, Pa., blasted an opening into an underground cave, while removing stone to be crushed for road material. Unfortunately, no one mineralogically inclined, entered the cave, which appeared to be small at that time. In the course of rock removal, the owner did, however, take out some massive white rock which he sold for rock garden material. Later Mr. Allen Heyl got into the cave for a short visit and reported many beautiful formations and several successive chambers each more beautifully covered with stalactites and arborescent formations. Unfortunately again the first five chambers were in the path of rock removal and subsequently were destroyed. About the early part of 1933 the writer was able to explore the remaining rooms and was permitted to remove the easier reached specimens. Many of the best were beyond reach as the main chamber was 25 feet or more in height and about the same in width.
>
> The formations were beautiful, and although the writer has been in many caves, he has seen none that were more attractive. As there are a number of caves in a small radius, the owner did not deem it profitable to commercialize on this one. The easy manner in which the surrounding rock can be quarried and the big demand for it for roads favored this decision.
>
> At present the main chamber is in process of destruction leaving two small chambers as yet untouched but not worthy of mention. There were nine rooms in all, each connected by a small alley or natural tunnel.

Another cave opening along the Lehigh Valley Railroad a short distance west of the Bethlehem Union Station can be entered for a short distance. A common rumor is that a person can enter here, pass under a considerable part of Fountain Hill and emerge at a small opening in an abandoned limestone quarry on Ostrum Street, a short distance northeast of the main buildings of St. Luke's Hospital. If this were possible it would be extremely disagreeable because of the large amount of house sewage that has been dumped into the cavernous limestones of Fountain Hill during the past hundred years or so.

Several fairly extensive caves exist in the vicinity of Guthsville, which were discovered during quarry operations. They are mainly narrow solution passages in the limestones. According to local reports some are wide enough for entrance and have been followed for a distance of 200 feet. Stalactites and stalagmites have been found in places.

Other Physiographic Features

In addition to the various physiographic features of Lehigh County just described there are a few others of somewhat more than passing interest.

Devil's Pulpit (Die Teufel's Kanzel). One of the rather striking features to be observed in passing through Lehigh Gap is a solitary pinnacle of the Tuscarora sandstone (pl. 12) about half way up the western slope. It is a remnant left by erosion when other outcropping portions of the same bed of sandstone were worn away. It presents some resemblance to a pulpit and was named more than 100 years ago.

Bake Oven and Bake Oven Knob. Near the northwestern corner of Heidelberg township a mass of Tuscarora conglomeratic rocks on the crest of Kittatinny (Blue) Mountain has an elevation of 1,600 feet above sea level. (Plate 12.) The mass rises about 100 feet above the fairly even crest of the main ridge. From this elevated point on a clear day a magnificent view can be had southward over the slate and limestone valley and northward over a series of ridges and valleys. At an earlier day the spot was frequently visited, but in recent years is seldom mentioned.

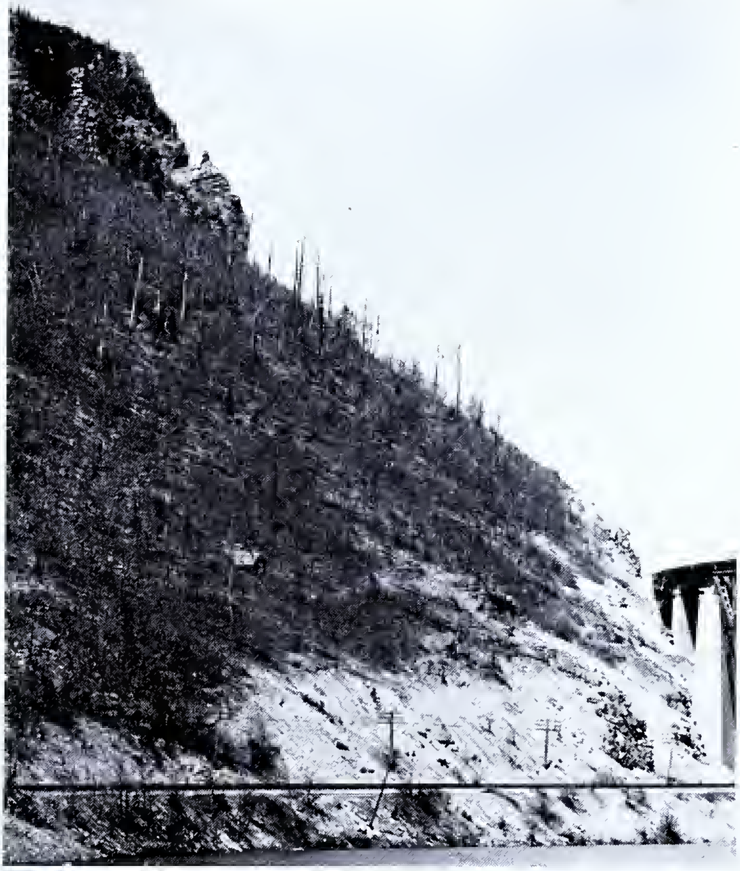
Almost at the base of the knob on the south side of the mountain there is a peculiar bowl-shaped excavation that has long been known as the Bake Oven because of its fancied resemblance to an old-fashioned bake oven. The prominent elevation nearby has naturally been called Bake Oven Knob.

As it is an unusual physiographic feature, it received the attention of the geologists of the Second Geological Survey of Pennsylvania, several of whom described it and attempted to account for its origin. The following quotations by J. P. Lesley are typical:

> After Mr. Hall's study of the Till, crushed slates, and sand-moraine barrier at the Lehigh Water Gap, by which he was led to the conclusion that a tongue-glacier had descended the Lehigh Valley to and perhaps through and beyond the Lehigh Water Gap, I thought I saw a mode explaining not only the anomalous Wind Gap, but the very curious half bowl scooped out of the south flank of the Blue mountain, beneath the Bake Oven Knob west of the Lehigh Water Gap. If this gap and the Delaware Water Gap were occupied, the one by a high wide tongue of ice banked against the Bake Oven, and the other by the great New York main glacier, then, although the sub-glacial waters would still issue by ice caverns through the two gaps, the residual surface glacial water would probably be obliged to pour over the crest of the Blue Mountain. If they did this at the Bake Oven for a short time, and at the Wind Gap for a long time, the only part of the problem of the genesis of these two remarkable topographical phenomena remaining unexplained would be, the selection of these two points along the crest in preference to any others. (Vol. G 6, 1882, p. 63.)
>
> The bowl under Bake-oven Knob six miles west of the Lehigh Water Gap is as mysterious as the Wind Gap. Here the mountain has not been gapped, only slightly notched at its crest; but a huge half bowl has been scooped out of its southern slope. Cliffs of rock a hundred feet high at the crest overhang the west side of the bowl; and at the top of the cliff the crest is almost 100 feet higher than anywhere else along the line of the mountain for fifty miles, so that the Bake-oven is a landmark for four counties.
>
> It looks as if the bowl had been made by some kind of water-fall; but if so the mass of water must have been extraordinarily great, and must have shot clear of the top of the mountain—an arrangement only possible in case the back valley were filled with ice to a height exceeding that of the mountain.
>
> All the difficulties encountered at the Wind Gap meet us here in an exaggerated form; and therefore a discussion of them is, for the present, useless. All the more, seeing that the geological survey has not yet been able to make contoured maps of the neighborhood. (Vol. Z, 1884, pp. xliv-xlv.)

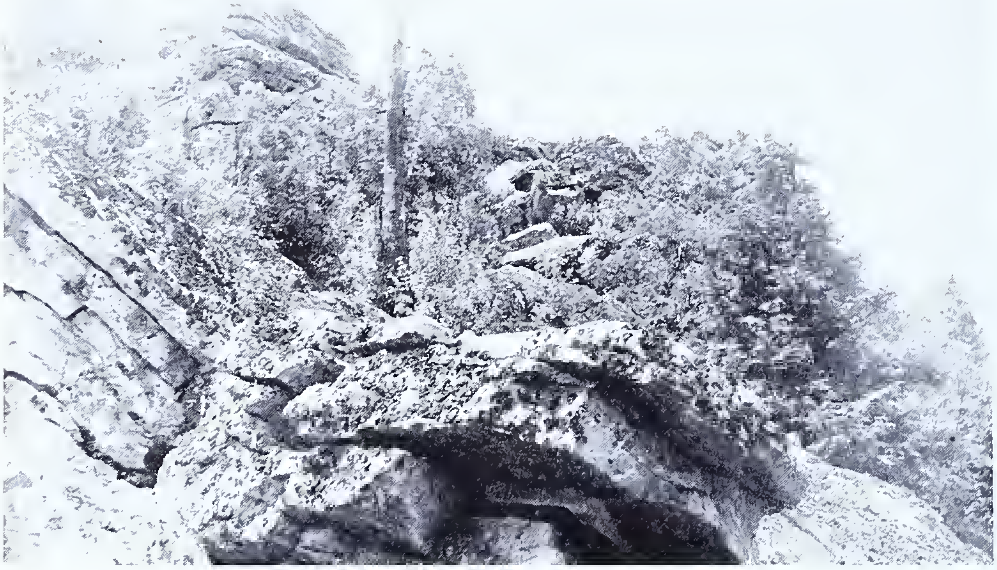
These explanations of Lesley do not seem plausible to the writer. Nor does it seem probable that glacial ice actually passed over the mountain at this point as has also been suggested.

The shape of the bowl is suggestive of cirque action at the head of a valley glacier. However, it is very doubtful whether any valley or

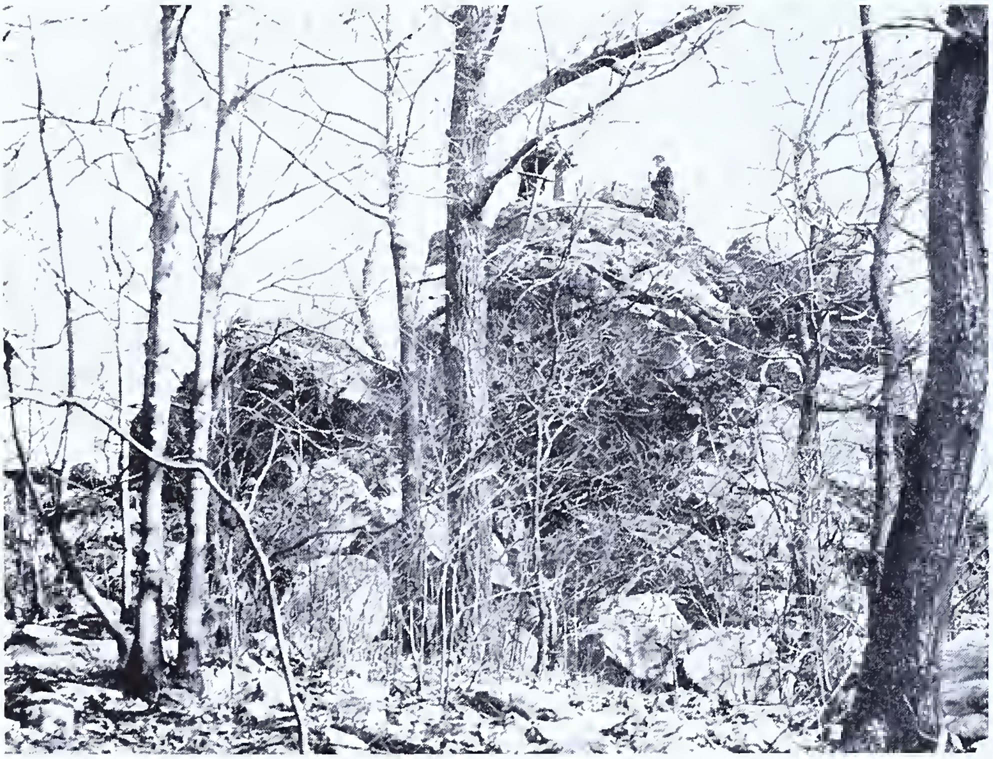


A. West side of Lehigh Gap. The rock in the upper third of the slope is Tuscarora sandstone. The small rock stack seen in profile is an erosion remnant known as The Devil's Pulpit.

B. Bake Oven Knob, crest of Kittatinny (Blue) Mountain.



A. Bear Rocks. Summit of Kittatinny (Blue) Mountain near Lynn-Heidelberg township line. Hard resistant sandstones of the Tuscarora formation.



B. Bauer Rock or Big Rock, top of South Mountain, southeast of Allentown. A residual mass of Pochuck gneiss rising precipitously above the general crest of the mountain and not of glacial origin as commonly believed. Perhaps the most generally known scenic feature of Lehigh County.

mountain glacier ever existed here. The more probable explanation is that the Bake Oven has been produced by differential weathering, principally alternate freezing and thawing of rain water that entered the cracks in the firm sandstones. The loosened rocks fell down the slope by gravity and in time found their way to the talus slope at the base of the mountain. The knob of rocks rising above the general mountain crest is also a result of differential weathering and erosion.

Bear Rocks. Another heap of Tuscarora conglomerate rocks on the top of the mountain about two miles southwest of the Bake Oven has been called Bear Rock or Bear Rocks (Plate 13). They likewise represent a small portion of these hard rocks that have resisted erosion somewhat better than the other rocks of the ridge.

Bauer Rock (Big Rock). At the summit of South Mountain a short distance southeast of Allentown is a mass of dark-colored Pochuck gneiss rising about 40 feet above the average level of the ridge. It is a prominent feature when the trees are bare and from its summit a gorgeous view can be had of Saucon Valley to the south and Allentown and surrounding region to the north. It has been variously designated as Bower's Rock, Big Rock, Mammoth Rock or the present name, and has long been famous as a picnic spot. Its top is 1,038 feet above sea level.

Occasionally one hears the feature explained as a collection of iceborne boulders. This is definitely false, as the rocks are in place and represent part of the basic gneiss forming the mountain. Less abundant cracks or joints seem to explain the greater relative resistance to erosion. (Plate 13.) There are several other slightly less conspicuous but similar knobs of the same rocks in the vicinity. Some of the joint planes in the gneiss are beautifully coated with a thin layer of epidote.

An appreciative description by I. Daniel Rupp (1845) is quoted:

> Numerous and interesting as the natural curiosities in this country are, there is none that so amply repays the adventurer as the Big, or Mammoth Rock, on the Lehigh hills, or South mountain, in this township. It is about three miles southeast from Allentown, and a jaunt to the hills forms a pleasant hour's walk. The Rock is easily ascended, though elevated a thousand or twelve hundred feet above the surrounding country. The spectator, while standing on this rupic eminence, has a commanding view of one of the most variegated sceneries imaginable. As far as the eye can reach, except on the north, where the vision is bounded by the Blue mountain, are spread before the eye, well cultivated farms, dotted with buildings; and the scene is greatly enlivened by the limpid stream of the Lehigh, as it winds its way down the Kittatinny valley. On the south, east and west, lie before you as a lawn, Saucon, with its rich limestone farms. Language fails to deliniate the scenery with any degree of graphic accuracy. (pp. 139-140.)

STRATIGRAPHY

Introduction

By Benjamin L. Miller

Lehigh County constitutes a part of the Appalachian Highlands which extend from Canada to central Alabama and from the Atlantic Coastal Plain on the east to the Interior Plains on the west.

The rock strata exposed in the county range from approximately the oldest to the youngest known on the North American continent, but with several major gaps. Most of the strata present have participated in two periods of earth disturbance of which the Appalachian Revolution at the close of the Paleozoic was the more profound. Folding and faulting have been so great that rarely does one encounter beds that are even in an approximately horizontal position. As a result of the complicated structures and repeated and long continued erosion intervals a greater variety of formations than is generally seen is present within the borders of the county.

Information concerning the geology has been accumulating for almost 200 years. The earliest settlement of the region took place about that time. During the first century of occupation, however, the information left to us concerning observations that may be regarded as of a geologic character is extremely fragmentary and of little present-day value. The second century is very different. From the beginning of the First Geological Survey of Pennsylvania in 1836 to the present, scarcely a year has passed without some contribution to our knowledge of the region. The numerous published articles and maps are listed in the Bibliography and Cartography contained in this volume.

The previously published descriptions are diverse and, almost without exception, concerned with distinct features or problems. The present volume represents the first effort to collect and evaluate all pertinent geologic data for the region.

In a sense which will undoubtedly be appreciated more by future investigators than by the present workers, this volume is of a preliminary character. Some of the problems discussed may be regarded by the individual writers as solved, but it is highly probable that our present conclusions may be set aside as new data, new methods, and new trends of thought develop. Other geologic problems of the region are frankly recognized as unsolved at the present time and such conclusions as are presented are regarded as tentative but in accord with existing data. If certain statements appear especially dogmatic it may be said that they are not so intended. These precautions are suggested for the general reader who cannot be expected to keep abreast of the constant changes in geologic interpretations that are taking place.

Not many decades ago such a report as this would have been prepared by a single author. A local geologist or a geologist sent to examine a certain region may have been able properly to collect, describe, and explain all the assembled data. At present this is not true. No longer can a geologist consider himself sufficiently trained in all the branches of geology represented by the rocks of such a region as that embraced in Lehigh County to justify him to undertake the sole preparation of such varied discussions as are here presented. The specialist in a particular field is the only one who is competent to discuss these varied distinct problems. For that reason this work is a composite one.

The writer began his investigations in the county in 1907 and has continued ever since. He has assigned students to specific places and he himself has repeatedly visited all parts of the county. However, a report on the entire county which he might have prepared would have lacked much. It is fortunate, therefore, that men who have specialized in particular phases or in strata of particular age were available for certain portions of the study. Somewhat different views exist among the authors of the volume, but such differences should not cause confusion nor militate against the usefulness of their contributions. At this stage of our science, universal agreement is impossible. In fact, greater progress is made under the stimulus of opposing opinions than when general acquiescence prevails. Different interpretations are welcomed.

The oldest rocks of the region, found in the South Mountains, are plainly the field of the petrologist, trained in the use of the microscope. The profound mineralogical and structural changes which the pre-Cambrian rocks have undergone during excessive metamorphism can only be described and explained by the microscopical study of thin sections. This part of the investigations lies within the particular province of Dr. Donald M. Fraser, who has had charge of the petrological work in the Department of Geology of Lehigh University since 1931 and who has devoted much of his time to the field and laboratory study of the local pre-Cambrian crystalline rocks. It is therefore appropriate that he prepare that portion of the volume concerned with these most ancient rocks.

The oldest rocks of the Paleozoic are the Cambrian sandstones of the Hardyston formation. In large part owing to the economic use of these sandstones for structural purposes and their association with the limonite deposits of the "mountain" type, they have received particular attention by the senior author. Under his direction considerable additional field work was done on this formation by P. B. Myers. The fact that George W. Stose and Anna Jonas Stose have advanced other views than those held by the writers has made it seem advisable to examine specimens of the rocks under the microscope. These investigations have been carried on by Dr. Fraser and Mr. Myers. For these reasons the Hardyston descriptions have been prepared jointly by B. L. Miller and P. B. Myers.

The Tomstown and Allentown formations of the Cambrian and the Beekmantown of the Ordovician are described by the writer. They are mainly composed of limestones, a group of rocks in which he has been particularly interested over a period of years. The economic, stratigraphic, and structural problems of these formations have been investigated by him more thoroughly than any of the other formations of the county.

In connection with investigations for his doctoral dissertation, Dr. Ralph L. Miller made a detailed stratigraphic study of the Jacksonburg formation in Lehigh and Northampton Counties. The assignment of this series of sediments to him therefore seems logical.

Dr. Charles H. Behre, Jr., while a member of the geological staff of Lehigh University, began an elaborate study of the slate deposits of Pennsylvania, later published in a report * by this Survey. This investigation was primarily economic, although necessarily concerned with stratigraphy and structure. Dr. Behre has not been available for a stratigraphical re-study of the Martinsburg formation, which contains practically all the workable slate deposits of the State, and therefore this field has been assigned to Dr. Bradford Willard. A re-study has become necessary inasmuch as the work of several persons in regions to the west and southwest has led to some new interpretations. Dr. Willard having made some of these investigations was the logical person to make the re-study of the Martinsburg of Lehigh County. His training and experience in stratigraphy and paleontology also fit him for the assignment.

The Triassic rocks of the extreme southwest part of the county are described by Dr. Edgar T. Wherry, who for many years carried on extensive investigations on this series of rocks. These resulted in numerous published articles. A considerable part of the Triassic belt of rocks of Lehigh County has previously been described by Dr. Wherry.*

The small area of Silurian rocks in the extreme north part of the county is described by the senior writer. He also has prepared the descriptions of the Pleistocene and Recent deposits. Although not a specialist in Glacial Geology, his associations with the men who have made the most intensive studies of these deposits has furnished him with their viewpoints. On numerous occasions he had the opportunity to accompany them in the field. Dr. E. H. Williams, Jr., and Dr. Joseph Barrell carried on the first investigations. The latest studies were made by Dr. Frank Leverett.

It is manifestly impossible to have closely similar treatment of the various topics discussed by these different writers. The individual subjects demand somewhat different treatment and, in addition, the personal element cannot be entirely eliminated. Therefore, there may appear to be little in common between the contributions of the different authors and it may be somewhat difficult for the general reader to obtain a clear picture of the entire region. A rather disjointed and perhaps unbalanced volume has resulted. This seems to be inevitable. This objection may be largely overcome by the final chapter on the geologic history of the region, in which is given, in sequence, a summary of the successive geologic events, so far as they are known, from the earliest records to the present.

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* Behre, C. H., Jr., Slate in Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. M 16, 400 pp., 1933.

* Bascom, F., Wherry, E. T., Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Quakertown-Doylestown district, Pennsylvania and New Jersey: U. S. Geol. Survey, Bull. 828, 62 pp., Washington, 1931.

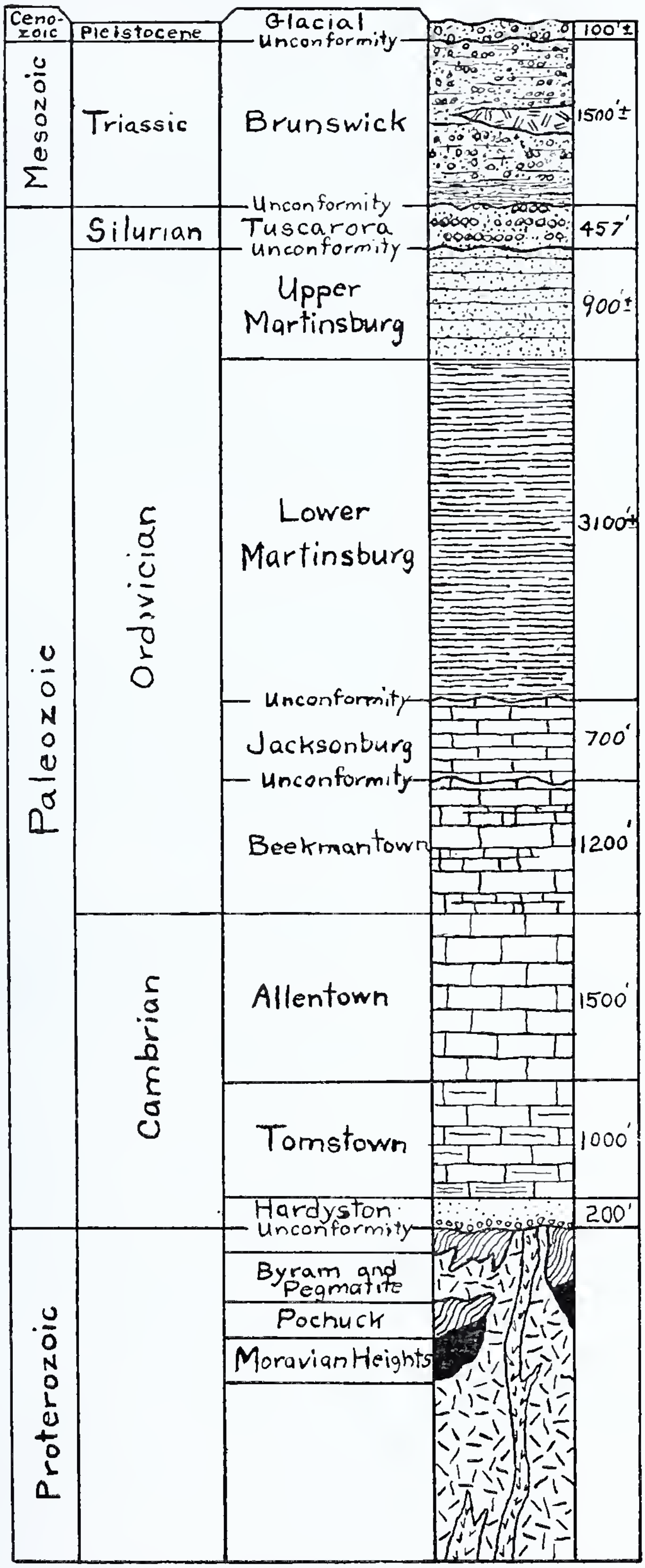

Figure 7. Columnar section of rocks exposed in Lehigh County.

STRATIGRAPHY AND PETROGRAPHY OF THE PRE-CAMBRIAN ROCKS

By Donald M. Fraser

General Statement

The pre-Cambrian rocks of Lehigh County occur in a belt about five miles wide which extends across the southeastern part of the county. The formations that make up the pre-Cambrian series include the Franklin formation, Moravian Heights formation, Pochuck gneiss, and Byram gneiss with associated pegmatites. In-folded and infaulted Paleozoic quartzite and limestone occur as irregular northeast-southwest bands within the pre-Cambrian area.

There is no good evidence of the age relations of the first three of these formations, all of which have been tentatively assigned to the Archean * and Algonkian. It is possible that the Franklin formation corresponds to the Grenville,† the Moravian Heights to a sedimentary formation of the Huronian, and the Pochuck gneiss to the volcanics of the Huronian.

The Byram granite gneiss and associated pegmatites are intrusive into the earlier formations. This period of invasion of granitic materials must have occupied a considerable time in the geologic past, but because of the general lack of prominent metamorphism in the Byram its emplacement probably represents a later rather than an earlier Proterozoic introduction of granitic material.

These tentative age assignments have been made without definite evidence and therefore must be regarded as somewhat unsatisfactory but at least they represent a reasonable sequence of formation for the rocks under consideration.

REVIEW OF PAST WORK

Early workers [1] in the pre-Cambrian of eastern Pennsylvania and New Jersey recognized the presence of a basic gneiss showing definite streaking and banding, an acid gneiss having less noticeable streaking, a metamorphosed limestone, and foliated gneiss and mica schist. The basic gneiss has been described by numerous workers as having been derived from a basic diorite or a gabbro. The acid gneiss has been identified at different times as a granite gneiss,[2] and as a quartz

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* The time scale or classification followed in this report is that used by the Pennsylvania Topographic and Geologic Survey. Ashley, G. H., A Syllabus of Pennsylvania Geology and Mineral Resources: Pennsylvania Topog. and Geol. Survey Bull. G 1, Plate 1, 1931.

† The U. S. Geological Survey considers the Grenville as Huronian in age. Wilmarth, M. G., The Geologic Time Classification of the U. S. Geological Survey compared with other classifications: U. S. Geol. Survey Bull. 769, Plate I, 1925.

[1] Britton, N. L., An. Rpt. State Geol., New Jersey for the year 1886, Pub. 1887.

Wolff, J. E. and Brooks, A. H., The Age of the Franklin White Limestone of Sussex Co., N. J.: Eighteenth An. Rpt. U. S. G. S., pt. II, p. 440, 1898.

Spencer, A. C., Kümmel, H. B., Wolff, J. E., Salisbury, R. D., and Palache, Charles, U. S. Geol. Survey, Geol. Atlas. Franklin Furnace folio (No. 161), 1908.

Bayley, W. S. Kümmel, H. B., and Salisbury, R. D., U. S. Geol. Survey Geol. Atlas, Raritan folio (No. 191), 1914.

Peck, F. B., Preliminary Report on the Talc and Serpentine of Northampton County and the Portland Cement Materials of the Lehigh District: Pennsylvania Topog. and Geol. Survey, Report 5, 1911.

[2] Spencer, A. C. and others, op. cit.

Jonas, Anna I., Pre-Cambrian and Triassic Diabase in Eastern Pennsylvania: Bull. Am. Mus. of Nat. Hist., vol. 37, pp. 173-181, 1917.

monzonite.[3] A third gneiss in the New Jersey district, of igneous origin and having a mineralogic composition intermediate between the Pochuck and the Byram was named "Losee Pond" by Wolff and Brooks.[4] Spencer [5] later shortened the name to "Losee." This formation has not been distinguished in the Lehigh County pre-Cambrian belt, and is considered to be one of the assimilation products formed by the invasion of the Pochuck by the Byram. Wherry [6] recognized and described the Moravian Heights formation as a quartz-sillimanite-sericite rock containing varying amounts of injected Byram material. The major units of the area, therefore, have been recognized for many years and the general relations fairly well understood. More recently Stose and Jonas have published [7] a structural interpretation of the area extending southwestward from a point south of Allentown, expressing views which the writer of this paper definitely opposes, but which have been of great value in stimulating interest in the structure of the pre-Cambrian belt. It is noted that Bayley has contributed considerable toward the knowledge of the pre-Cambrian of New Jersey.

ACKNOWLEDGMENTS

The writer expresses his deep appreciation to the senior author for encouraging the study of the pre-Cambrian formations. In addition, a map of the pre-Cambrian area within the Allentown quadrangle made by Wherry and Miller was of great value in re-mapping that part of Lehigh County. The writer has used freely the information presented by Wherry in a manuscript on the pre-Cambrian of the Highland belt of eastern Pennsylvania. Numerous discussions with B. L. Miller, E. T. Wherry, G. H. Ashley, B. Willard, R. D. Butler and J. W. Peoples have assisted materially in the interpretation of the formational relationships of the area.

A National Research Council grant for thin sections is gratefully acknowledged.

Formation Description

GENERAL STATEMENT

The formations of pre-Cambrian age in Lehigh County to be described in detail include the Franklin formation, which in adjacent areas consists of the Franklin limestone and a quartz-graphite schist, but here is represented by only the latter member; the light-colored, tan to greenish Moravian Heights formation with streaks of sericitized sillimanite in a quartz-feldspathic groundmass; the Pochuck diorite gneiss made up of approximately equal amounts of light-colored feldspar and dark-colored hornblende so that it appears as a relatively dark "salt and pepper" rock in the field; and the Byram granite and granite gneiss composed chiefly of feldspar and quartz and occurring as a light-colored rock in the field.

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[3] Bascom, F., Wherry, E. T., Stose, G. W., and Jonas, A. I., Geology and Mineral Resources of the Quakertown-Doylestown District, Pennsylvania and New Jersey: U. S. Geol. Surv. Bull. 828, p. 13, 1931.

[4] Wolff, J. E. and Brooks, A. H., op. cit., p. 430.

[5] Spencer, A. C., Kümmel, H. B., Wolff, J. E., Salisbury, R. D., and Palache, Charles, op. cit., p. 5.

[6] Wherry, E. T., Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania: Geol. Soc. America Bull., vol. 29, pp. 375-392, 1918.

[7] Stose, G. W. and Jonas, A. I., Highlands near Reading, Pennsylvania; An Erosional Remnant of a Great Overthrust Sheet; Geol. Soc. Am. Bull., vol. 46 (1935), pp. 757-779.

The interpretation of the mapping of the pre-Cambrian rocks of Lehigh County will be facilitated by an understanding of the assumptions made at the time of the mapping of the area. None of the pre-Cambrian formations show clean-cut contacts with any of the other formations older than the Hardyston. The Franklin formation and the Moravian Heights formation, both of which are interpreted as having been formed from primary sediments, do not give evidence of their respective ages and their structural relations to the Pochuck gneiss are not exposed. The Byram granitic material, which in places shows an indistinct gneissic structure, everywhere shows intrusive relations to the above-mentioned three formations. The general situation throughout the area is that the earlier three formations are very intimately invaded by granitic material. Pegmatitic material in part probably accompanying the Byram invasion and in part as late as post-Hardyston, has also injected earlier formations.

On the geologic map, formation contacts are represented by solid lines rather than dots or dashes. These solid lines do not, however, indicate a clean-cut, readily recognized and accurately determined contact plane. They indicate that in so far as the author of the map was able to judge, the materials on either side of a zone having the approximate location of the line on the map were of two types. Commonly, a decision had to be reached on the difference between the invading Byram gneiss and one or the other of the older formations containing abundant introduced Byram material.

The fairly consistent northeast-southwest strike of the formations has resulted in a similar alignment of the remnants of the injected materials.

Within the larger areas shown as either Pochuck gneiss or Byram granitic gneiss, one may expect to find small injections or inclusions of the other material, but within any area indicated as one or the other of these formations, the expectation is for a preponderance of that material.

FRANKLIN FORMATION

Distribution.—In the southern part of the county in the district east and southeast of Vera Cruz blocks of quartz-graphite schist occur in several small areas. A larger occurrence is shown on the map approximately one mile east of Bald Hill, which lies just north of Hosensack; a small patch of this same material is found on the ridge west of Powder Valley. Probably other small localities will be found, but in no place does the material crop out in a well-developed form.

Lithologic characteristics.—The quartz-graphite schist member of the Franklin formation normally consists of quartz grains in which are imbedded numerous scattered flakes of graphite. Except where invaded by later igneous material the feldspar content is low. In some of the districts where this member has been mapped the rock may consist mostly of introduced Byram granite, which has caught up and partially assimilated the older formation. If it were not for the presence of graphite flakes it is likely some of the occurrences would not have been noticed.

The texture usually is uniform, the grain size ranging from one to two or three millimeters. In hand specimen the structure ranges from massive granulose to poorly schistose.

Thickness.—The thickness of the quartz-graphite schist cannot be determined because there are no measurable outcrops, but on the basis of the extent of the float material it may be assumed to be a few tens of feet thick. In all probability it was originally several tens of feet in thickness and must have been of considerable areal extent because it is found scattered throughout an area of many tens of square miles in the pre-Cambrian belt of eastern Pennsylvania.

Name and correlation.—The Franklin formation in this area has been tentatively correlated with the Franklin limestone of New Jersey, which was named by Spencer,[8] in the area of Franklin, New Jersey. The true sedimentary origin of the Franklin formation was determined as early as 1898 by Wolff and Brooks.[9] These authors credit the earliest mention of the formation to William Maclure in 1809, who described a ''large-grain marble on the edge of the Formation, near Sparta.'' The formation was studied and discussed by a number of workers following Wolff and Brooks, and in 1908 Spencer and others described the ''Franklin limestone'' in detail. This is apparently the first use of the term Franklin to designate the formation which had previously been discussed as the ''white limestone'' in distinction with the ''blue limestone'' of Paleozoic age found in the vicinity.

In the study of the geology of Northampton County the associated graphitic quartz schist was included with the limestone to comprise the Franklin formation. This was done because of their association in the field and the prevalence of graphite in both members, probably indicating their mutual sedimentary origin. The Franklin formation is considered to be Archean in age, roughly equivalent to the Grenville limestone of the Adirondack area.

Stratigraphic and structural relations.—Without having definite evidence for doing so, the Franklin formation is thought to represent the oldest or certainly one of the oldest formations in the district. It occurs in only small isolated areas, and with the exception of the Moravian Heights formation, which also has a small areal distribution, the Franklin formation is present in much smaller areas than the other pre-Cambrian rocks. The assumed sequence of origin places the Franklin formation first, Moravian Heights second, and the Pochuck gneiss third. It is not possible to show the nature of the contact between any two of these three formations, and their relative positions in the field have not helped to determine the super-position of one to the others.

Petrography and petrology.—Under the microscope specimens show a rude schistosity due to the slight elongation of some quartz grains and the sub-parallel arrangement of the graphite flakes. The grains are three millimeters or less in diameter, giving in general a fine-grained appearance to the rock.

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[8] Spencer, A. C. and others: op. cit.

[9] Wolff, J. E. and Brooks, A. H., op. cit.

The material is the result of recrystallization, under dynamic metamorphic processes, of a former carbonaceous sandstone.

MORAVIAN HEIGHTS FORMATION

Distribution.—Small areas of the Moravian Heights formation occur in the northeastern part of the pre-Cambrian area of the county. The larger of the two that occur south of Bethlehem is a little over a mile long from north to south and about one-fourth of a mile wide. In this area and a smaller district to the southwest the Moravian Heights formation is recognized by the occurrence of streaks of serpentine-like material in gneissic rocks.

Lithologic characteristics.—Hand specimens characteristically show streaks and bands of sericitic to serpentine-like material (formed from sillimanite) surrounded by mosaic quartz or quartz and feldspar. In the field the material often occurs in rhombohedral blocks which have resulted from close-spaced jointing in the formation.

Thickness.—The Moravian Heights formation has been greatly thickened by the injection of igneous material. It is impossible to estimate the thickness of the formation as it now exists or as it existed in its original state. As a rule the mapping has been done on the assumption that wherever streaks of sericitic and sillimanitic material are at all common the rock is the Moravian Heights formation. In many places an assumption of this sort has resulted in the mapping of Moravian Heights where by far the greatest volume of material is the injected granitic minerals. In general, therefore, we may interpret the areas of Moravian Heights as being areas in which Moravian Heights material has been injected by a later granitic magma.

Name and correlation.—This formation, which occurs as a quartz-sericite-sillimanite schist, has been described in previous publications.[10] Drs. B. L. Miller and E. T. Wherry and other workers who have had a part in mapping the geology of the Bethlehem district have long used the term Moravian Heights formation to designate this rock. The name Moravian Heights, taken from a district near Bethlehem, appeared in print for the first time in the Northampton County report (Bull. C 48), although it has been in local use for many years. Because both have been formed from sedimentary materials and show a comparable degree of metamorphism, the Moravian Heights and the Franklin are considered to be of approximately the same age. It should be added that both have suffered dynamic metamorphic changes and later injection. In the absence of satisfactory evidence for the age of the Moravian Heights, it has been tentatively assigned to the Huronian.

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[10] Miller, B. L., Topographic and Geologic Atlas of Pennsylvania. 206, Allentown Quadrangle, p. 144, 1925.

Wherry, E. T., Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania: Geol. Soc. America Bull., vol. 29, pp. 379-385, 1918.

Fraser, D. M., Pre-Cambrian Rocks and Paleozoic Igneous Rocks of Northampton Co.: Topog. & Geol. Survey of Pennsylvania Bull. C 48, p. 172, 1939.

Structural relations.—The Moravian Heights is commonly found as blocks on the slopes of the hills, and in only a few places are definite outcrops of the formation seen. Where such outcrops occur, the streaking or banding, which has been determined by injection along the planes of schistosity, is usually measurable. Contacts of this formation with other pre-Cambrian rocks, except the injection relations of the Byram, have not been observed in the county.

Petrography and petrology.—In thin-section the Moravian Heights formation invariably shows linear to tabular schistosity. This structural appearance is due both to orientation of sillimanite needles and a stretching of quartz grains of the original material, and to invasion of the formation along parallel planes by a later granite magma. Most types of the Moravian Heights are very rich in quartz. The sillimanite needles occur as inclusions in quartz grains, as aggregates of smaller prisms extending across the boundaries of several quartz grains, and as larger single prismatic or acicular crystals that give a streaked appearance to the rock. The quartz grains are commonly stretched and in some cases considerably elongated so that they may be six or eight times as long as they are wide. It appears that the material had been subjected to dynamic metamorphism which resulted in the recrystallization of quartz to produce greatly elongated grains, and of the original argillaceous material to form the present sillimanite. That some of the stress conditions of this period or later were not entirely relieved by recrystallization is indicated by the abundance of strain shadows observed in the quartz grains.

Wherry [11] has described this rock and has discussed its mineralogy with a table of the minerals found, and their percentages, as given below.

	1	2	3	4
Quartz	55.4	52.6	49.7	50
Sericite	5.9	40.0	15.7	20
Sillimanite	35.1	6.8	24.3	25
Accessories	——	——	——	5
Feldspar (altered)	——	0.4	5.0	—
Biotite	1.6	0.1	——	—
Ilmenite	1.95	0.05	——	—
Pyrite (and limonite)	——	——	5.2	—
Zircon	0.05	0.05	0.05	—
Apatite	——	——	0.05	—
	100.00	100.00	100.00	100

1. One mile west of Seidersville (206).
2. Two miles southeast of Freemansburg (217).
3. East edge of Allentown quadrangle, one mile south of Lehigh River (6396). (Two miles east of Redington.)
4. The rounded-off average of 1, 2, and 3.

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[11] Wherry, E. T., Pre-Cambrian Sedimentary Rocks in the Highlands of Eastern Pennsylvania: Geol. Soc. America Bull., vol. 29, pp. 375-392, 1918.

Wherry discussed the origin of this material and on the basis of mineralogical and structural evidence suggested its derivation from an original sedimentary type. He concluded that the presence of sillimanite indicated a noteworthy alumina content of the original sediment and thought that very likely the material was originally an argillaceous sandstone. The present writer[12] has discussed the sericitization of certain types of the Moravian Heights and has found that the areas of sericite encroach upon and cut across the stretched and strained quartz crystals shown in the thin sections. This would indicate that the alteration had occurred definitely later than the stress responsible for the oriented crystals. In all probability, we may assume that the original sedimentary material, which was likely a shaly sandstone as interpreted by Wherry, was completely metamorphosed into a quartz-sillimanite schist with, very likely, accompanying mica, before the introduction of the solutions responsible for the sericitization.

In its present form the Moravian Heights commonly shows only scattered remnants of the original sillimanite needles. In some places the thin sections indicate the former presence of occasional sillimanite prisms only by the occurrence of small square areas now occupied by sericite scales and fibres. Such square cross-sections of sillimanite partially altered to sericite are found in other thin sections and indicate the true nature of these bodies in the rock.

With the invasion of a granitic magma, the Moravian Heights formation was acted upon by at least two major processes: (1) The formation was intimately injected by granitic materials which parted the original schistic and gneissic planes and introduced granite layers between them. This type of material is that which most commonly occurs in those districts indicated as Moravian Heights. In some of these specimens the volume of introduced granitic material is dominant over that of the primary material. (2) At a later period, hydrothermal solutions attacked the Moravian Heights formation and altered the rock in part to sericite. The breaking down of the original minerals resulted in the sericitization of the sillimanite first, with the partial sericitization of quartz, following or accompanying this other change. As observed at present, therefore, the Moravian Heights rocks are considerably recrystallized and hydrothermally changed. What was originally an argillaceous sandstone is now partially sericitized layers and lenses of material often largely dominated by the invading granite mass.

Local details.—One of the better localities in which the Moravian Heights formation may be examined is a quarry approximately a quarter of a mile southeast of Gruver School, which is about one mile east of Mountainville. Decomposed granite and granite sand have been obtained from this quarry. The walls of the quarry and broken material on its floor include some blocks which show greenish streaks indicating the presence of sillimanite and sericite derived from the Moravian Heights material. In the fields north of the quarry are occasional float fragments of light-colored granitic material in which one finds occasional streaks and patches of sillimanite and associated sericite. In some hand specimens obtained in this region one may distinguish bands of quartz-sillimanite-sericite-schistose material alternating with thicker bands up to possibly an inch or more of introduced granitic material. These latter zones consist chiefly of quartz and light-colored feldspar which, under the microscope, proves to be both oligoclase and microcline.

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[12] Fraser, D. M., Sericitization in the Pennsylvania Highlands: Proc. Penn. Acad. Sci., vol. X, pp. 66-71, 1936.

From an examination of the Moravian Heights in this relatively small district one can well appreciate the statement that where Moravian Heights areas are shown on the map we are merely indicating regions in which some Moravian Heights material appears. Most of the volume of rock materials in these districts is composed of the later Byram intrusive granite.

POCHUCK GNEISS

Distribution.—Areas of Pochuck gneiss are small but scattered throughout the county in the pre-Cambrian belt. The largest district underlain by Pochuck is in the southern part of the county in the vicinity of Sigmund and Old Zionsville. In this district and also to the northeast the occurrence of Pochuck is in elongated zones in the Byram. These zones extend northeast and southwest, usually for distances of not more than two or three miles, and range from roughly a mile down to only a few hundred yards in width. In the northeastern part of the county, Pochuck is somewhat less abundant and occurs in irregular areas which do not show a parallel alignment as do those to the southwest.

Lithologic characteristics.—A gneissic structure is usually present in the Pochuck gneiss. This is caused by the orientation of hornblende or biotite grains parallel to a plane or a direction, and in part by the grouping of these minerals into parallel streaks or irregular bands. Where the formation has been invaded by the Byram granitic material, the gneissic appearance may be accentuated by the alternate light and dark layers that result from this intrusion. In the field the Pochuck commonly appears as a dark green or greenish-black rock which may or may not show structural directions or weakness. If the rock has suffered silicification, as much of the material has, the tendency to break along the gneissic directions is often completely lacking.

Although the Pochuck is generally composed of hornblende and andesine, it shows many variations in composition. Biotite-andesine facies appear as well as hornblende-pyroxene-andesine facies. They grade into each other and both grade from their purer form into types in which Byram granitic material dominates.

Thickness.—The Pockuck gneiss is of such irregular occurrence and shows so few contact relations with other formations that its thickness is impossible to determine. If it is the metamorphosed equivalent of a former diorite or diorite gabbro, the subject of thickness would be omitted; if it has been formed from lava flows we might expect its original thickness to be possible of determination in some way, but no evidence along this line has been observed.

Name and correlation.—This formation was given its name by Wolff and Brooks[13] from Pochuck Mountain in New Jersey. They describe it as follows:

> The gneissic outlier of Pochuck Mountain is represented by two bands of rock. The eastern band, which adjoins the valley and forms the eastern slope of Pochuck Mountain, we have called the Pochuck gneiss. This gneiss is about half a mile in width, and has been traced from near Hamburg to the northern edge of the area mapped. The prevalent rock type is a finely foliated gneiss, rich in biotite and hornblende, and often grading into a mica schist. With this mica-hornblende gneiss are often associated bands of amphibolite-gneiss. The latter rock consists essentially of plagioclase, green hornblende, and quartz, with some biotite, and is probably a squeezed dioritic rock.

In New Jersey the Pochuck as described by Spencer[14] and others is used "to include all the gneisses occurring in the Highlands region that contain hornblende, pyroxene or mica as principal mineral constituents. Some of these rocks are probably of sedimentary origin, and others may be altered igneous rocks, but in general they are so completely metamorphosed that their original nature cannot be ascertained." In the Raritan quadrangle, Bayley states:

> The rocks included in the Pochuck gneiss are all dark colored and generally black, on account of their large content of pyroxene, hornblende, and biotite. They have a wide range in mineralogic composition and are composed mainly of oligoclase, orthoclase, diopside, hornblende, hypersthene, biotite, magnetite, and quartz, in various proportions. Some specimens contain all these minerals, but as a rule two or more are absent. Magnetite is the most constant component, though oligoclase and hornblende, and green pyroxene are generally present.

It will be seen that the materials considered as Pochuck by Wolff and Brooks included not only the dark colored gneissic or schistose material but also foliated gneiss and mica schist. The later workers tended to confine the name Pochuck to the dark colored gneissic or schistic material. The present writer uses the name Pochuck for the dark colored gneisses containing hornblende, pyroxene and (or) biotite as dark constituents and oligoclase-andesine or andesine-labradorite as the more common plagioclase minerals. Quartz and magnetite are commonly present, and titanite, chlorite, epidote and other minerals appearing as accessory or secondary minerals are not infrequent.

Origin.—Spencer and others thought the Pochuck was derived from both sedimentary and igneous rocks. Bayley[15] concludes as follows:

> It therefore seems probable that the black gneisses which have been included under the term Pochuck gneiss should properly be divided into two groups of different age and possibly of different origin, the first group comprising gneisses, possibly of sedimentary origin, older than the Byram and Losee gneisses, and the second group comprising dark gneisses of igneous origin contemporaneous with the Byram and Losee gneisses.

The present writer considers the Pochuck as described in this report to be entirely of igneous origin. Furthermore, he wonders if the original form of this material may not have been andesitic and basaltic lava flows. The composition of the present material, excluding the great volume of introduced silica, which of course raises the total silica content, is such that the material might have been originally of flow origin. The considerable linear extent of this formation, although certainly not excluding the diorite or diorite gabbro origin, would conform very well to the flow hypothesis.

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[13] Wolff, J. E. and Brooks, A. H., op. cit., p. 440.

[14] Spencer, A. C., and others, op. cit., p. 4.

[15] Bayley, W. S., Kümmel, H. B., and Salisbury, R. D., op. cit., p. 63.

If it could be shown that the Pochuck gneiss has been derived by the metamorphism of flow rocks of intermediate and basic character, it might be thought to be equivalent in age to one of the pre-Cambrian lava series of the northern Great Lakes area. It may be suggested that the Pochuck be correlated with lavas of the Huronian.

In answer to the suggestion that the Pochuck has been derived from the lavas of Keewanawan age, the close association with the Franklin and Moravian Heights formations and the more definite metamorphism of the Pochuck than the Byram granitic material have been the deciding factors in arriving at a tentative conclusion that the Pochuck, if of lava flow origin, is more likely to be correlated with the Huronian than the Keewanawan.

Stratigraphic and structural relations.—Little field evidence is available to indicate the relative stratigraphic position of the Pochuck gneiss with either the Franklin formation or the Moravian Heights. It has been tentatively assumed that the latter two are older than the Pochuck. They may occur in adjacent areas but they are not exposed in contact in stream valley, road cut, or quarry.

The relations with the Byram granitic material are very definite. The Pochuck is the older rock and has been invaded and assimilated in varying degrees by the younger formation. This invasion occurred at a depth in the earth's crust sufficient to result in a plastic state of the Pochuck at the time of the entrance of the Byram. Contorted schlieren of the Pochuck material are found in the Byram near the contact with definite Pochuck gneiss. All stages are found from 100 percent Pochuck material composed of hornblende and andesine to 100 percent Byram composed of quartz, microcline, microperthite, and orthoclase. In this range there are, of course, types which show the entrance of small amounts of quartz and orthoclase into the Pochuck, types in which the rock is a typical mixed material with about equal amounts of invading and invaded minerals, and types in which scattered grains of hornblende and saussuritized andesine in Byram material are the evidence of incorporated Pochuck. The structural relations, therefore, of the Pochuck and the Byram are those chiefly of the invasion and assimilation of the former by the latter; this invasion being extensive and intimate.

Petrography and petrology.—In thin section the Pochuck gneiss is found to be more variable than one would expect from an examination of the hand specimens in the field. Megascopically, the material is characteristically a speckled granulose type of rock possessing a rude structural alignment. The minerals observed in the hand specimen are recognized as hornblende and plagioclase feldspar. In addition, certain phases contain biotite with or without hornblende and (or) pyroxene. Some phases contain rather abundant hornblende and pyroxene crystals. Under the microscope the plagioclase varies from oligoclase to labradorite in composition. The accessory minerals are apatite, magnetite, titanite, zircon and occasional other grains of much less abundance. The material commonly alters by the development of hornblende from pyroxene and the breaking down of plagioclase to produce saussurite. Epidotization is common where silicification of the Pochuck is prominent.

Analysis of the Pochuck gneiss[16]

W. T. Schaller, Analyst

SiO_2	43.98	K_2O	1.10
Al_2O_3	12.01	H_2O	.29
Fe_2O_3	6.60	H_2O+	1.04
Fe_2O	12.20	TiO_2	2.25
MgO	5.46	CO_2	.18
CaO	11.99	P_2O_5	.28
Na_2O	2.93	MnO	.05

The introduction of a large volume of silica into the pre-Cambrian formations is an interesting feature of these rocks. It is at times accompanied by microcline and (or) albite and apparently has been derived from a granitic magmatic source. In certain localities the introduced silica runs as high as 15 percent and has resulted in the development of quartzitic types of rocks from the normal Pochuck and other associated formations. In the case of the Pochuck gneiss, the granitization or silicification, as the case may be, has been accomplished by the encroachment of quartz and microcline and (or) albite upon plagioclase dominantly, but also upon hornblende, pyroxene or biotite in many instances. These encroachment areas are irregular in shape and a single one may attack two or more grains of the original minerals of the rock. The resultant structure resembles the interlocking outline of a jigsaw puzzle. With a more active type of invading material, the original minerals of the Pochuck may be completely absorbed by the introduced magmatic material. This results in an increase in the lime content of the then liquid mass, over that of the introduced magma, which, upon later crystallization, produces a plagioclase less calcic than that found in the normal Pochuck but more calcic than would have resulted from the crystallization of the invading material before the assimilation of the basic rock. This process was recognized by Wherry,[17] who described the basic gneiss many years ago. More recently the writer[18] has described assimilation relationships of the Byram to the Pochuck as exhibited by the rocks of the area south of Macungie, Pa. One may expect to find every stage of assimilation ranging from small amounts of quartz and alkali feldspar introduced into the Pochuck to rocks composed of quartz, oligoclase, microcline and hornblende, which represent the solidification of the granitic magma plus the assimilated Pochuck gneiss.

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[16] Pardee Mine, Franklin Furnace Quadrangle: U. S. Geol. Survey Geol. Atlas, Raritan folio, field edition, p. 61. 1914.

[17] Wherry, E. T., op. cit.

[18] Fraser, D. M., Igneous assimilation near Macungie, Pennsylvania: Proc. Penn. Acad. Sci., vol. IX, pp. 34-38, 1935.

Structure.—The structure of the Reading Hills has been discussed at length in publications [19] by various workers during recent years. The reader is referred to these papers for the arguments regarding various interpretations of the structural relations of this region. A brief statement of the writer's conception of the structure of the pre-Cambrian belt of the county, however, is appropriate here.

It is thought that the pre-Cambrian rocks now stand in relief because they have been folded and faulted in such a manner that the overlying Paleozoic formations have been dropped below the more resistant pre-Cambrian rocks in adjacent blocks or up-folded belts. A generalized picture of the structure may be gained if we assume a northwest-southeast section across the Reading Hills. In such a section we find the pre-Cambrian rocks occupying the hills and the Paleozoic formations dipping outward from the pre-Cambrian areas or faulted down in the valleys between the pre-Cambrian ridges. A section indicating the generalized NW-SE structure of this belt (fig. 8) is taken from the southwestern edge of the county. It will be noted that at the northwestern end of the section the Paleozoic formations dip northwestward from Lock Ridge, which is made up of pre-Cambrian crystalline rocks. The southeastern edge of Lock Ridge is in fault contact with Paleozoic formations of the low-lying valley. The next ridge to the southeast also is made up of pre-Cambrian crystallines with Paleozoic formations dipping northwestward from them. Low-lying areas of Paleozoic limestone occur within this pre-Cambrian belt, as shown near the center of the section, and are interpreted as having been down-folded and down-faulted into the pre-Cambrian rocks.

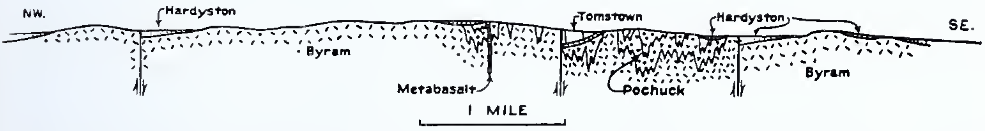

Figure 8. Cross section of the pre-Cambrian belt of Lehigh County, drawn along the Berks-Lehigh County line.

Some workers [20] have suggested that the pre-Cambrian belt in Lehigh County has been thrust from some miles to the southeast over the Paleozoic formations into the present position. This infers that the present pre-Cambrian ridges are underlain by a thrust plane below which are Paleozoic sediments. The present writer does not accept this hypothesis of the structure of the region because of the following reasons: 1. Although faulting is abundant in the district, and high-angle fault surfaces can be seen in several places, there is no good exposure that indicates extensive thrust movement. 2. The occurrence of Paleozoic formations dipping northwestward from the northwest edge of the pre-Cambrian belt implies a normal sequence which would be highly unlikely if the pre-Cambrian rocks had been thrust from some distance to the south. 3. Drilling operations in several places in the county and nearby area have shown the pre-Cambrian-Paleozoic relationships to be incompatible with an extensive overthrust of the pre-Cambrian area as a whole.

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[19] Stose, G. W., and Jonas, A. I. (1936), Highlands near Reading, Pennsylvania; an erosion remnant of a great overthrust sheet: Geol. Soc. Am., Bull., vol. 46, p. 757-780.
Miller, B. L., and Fraser, D. M. (1936), Comment of "Highlands near Reading, Pennsylvania; an erosion remnant of a great overthrust sheet:" Geol. Soc. Am., vol. 46, p. 2031-2038.

Fraser, Donald M. (1938), Contributions to the geology of the Reading Hills, Pennsylvania: Geol. Soc. Am., vol. 49, p. 1199-1212.

[20] Stose, G. W. and Jonas, A. I., op. cit.

METADIABASE

A fine-grained, dense, greenstone type of rock is found in float blocks in increasing abundance as one passes through Lehigh County into Berks County to the southwest. Hand specimens appear to be altered basalt and diabase. They are in general greenish to black and often give the impression of having a matted texture. This material likely represents basic dikes cutting the rocks of the district at irregular intervals.

Mineralogic composition.—The microscope shows this rock is composed of secondary feldspar, epidote, chlorite, magnetite, and introduced quartz. The primary minerals are interpreted to have been augite, labradorite, and magnetite. These have been changed hydrothermally to the above list of alteration minerals. It is likely that the quartz is largely introduced, although some smaller grains may have been formed from the hydrothermal breaking down of the previously existing minerals. In general, however, the quartz areas are irregular and have somewhat rounded contacts with other minerals. This has led the writer to believe the quartz was introduced because if it had been formed from the primary minerals, more intimate intergrowth relations would likely have resulted. Furthermore, the silica content of the original diabasic or basaltic material likely was too low to result in the present mineral assemblage plus the frequent areas of quartz.

The textures shown under the microscope include a trachytoid arrangement of labradorite laths in a fine-grained groundmass of augite, magnetite, and andesine-labradorite, flow-structure due to the parallel arrangement of andesine-labradorite laths and the more common diabasic and ophitic textures.

Age relations.—The age relations of this basic material to other rocks in Lehigh County are obscure, but its occurrence in areas of pre-Cambrian rocks and Hardyston quartzite would indicate it may be either Paleozoic or pre-Cambrian in age. A previous paper[21] describing this material gives the reasons for considering it to be of probable Ordovician or post-Ordovician age.

HISTORICAL GEOLOGY

The earliest event recorded in the rocks of Lehigh County was the deposition of quartzose sands with included carbonaceous material. At approximately the same time or closely following the accumulation of the sands a series of argillaceous sands was also laid down. The accumulation of these two types of materials at this early time is indicated at present by the quartz-graphite schist of the Franklin formation and by the Moravian Heights formation.

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[21] Fraser, D. M., Basic Rocks in the Eastern-Pennsylvania Highlands: Am. Geoph. Un. Trans., 18th An. Meet., 1937.

Following the early sedimentary accumulations there was an extensive period during which basic igneous rocks invaded the region. These are thought to have followed the sediments because of their present greater areal extent. Although the basic materials may have been introduced as coarse-grained intrusives, the writer is inclined to favor the view that they were extruded as lava flows.

This series of sedimentary and igneous formations was then metamorphosed by recrystallization under what were probably dynamic conditions. This resulted in the formation of quartz-graphite schist from the carbonaceous sandstone and of quartz-sillimanite schist from the argillaceous sandstone. The basic igneous rocks were altered to basic gneisses by the same processes.

Such a metamorphic history implies reasonably deep burial of the formations during the change. During the later stages of metamorphism, or possibly much later, the entire district was invaded by magmatic material. This developed great granite batholiths reaching into the earlier formations. The intimate penetration and extensive assimilation of the earlier formations by the invading material indicates that the intrusion occurred at considerable depth. Subsequent uplift and erosion have exposed the invading granite in large areas while the earlier formations occur only in small remnant patches. Some time during the later pre-Cambrian period dynamic forces altered the Byram locally to produce certain gneissic and cataclastic facies.

Local details.—One of the areas in which Pochuck gneiss is well exposed is that in the vicinity of Bauer (Big) Rock and extending southwestward to Summit Lawn at the crest of the mountain south of Mountainville. In the vicinity of Bauer Rock one finds the typical hornblende-andesine type of Pochuck showing the characteristic salt and pepper appearance. Some blocks show somewhat better streaking or gneissic banding than do others, but it is only occasionally that continuous well-defined bands appear. For the most part one sees only a rude gneissic structure. Northeast of Bauer Rock is a zone of more abundant Byram granitic material, and at the hill approximately half a mile northeast of Bauer Rock the main volume of rock is the Byram intrusive granite. Other areas in the county show similar gradational relationships. We could suggest the two larger areas of Pochuck as shown on the map north of Vera Cruz as showing the typical intrusive relationships of the Byram granite to the older basic gneiss. In both of these areas one finds abundant Pochuck which gradually changes to an abundant Byram at the indefinite limits of the Pochuck as shown on the map.

BYRAM GRANITE GNEISS

Distribution.—By far the greatest area of the pre-Cambrian portion of the county is underlain by Byram granite and granite gneiss. This is the formation that makes up the great body of the hills of the Reading Prong extending across the southeastern edge of the county. In general the picture is one of mountainous belts of Byram (with only small patches of the other pre-Cambrian formations) separated by narrow valleys in which Paleozoic sandstones and limestones occur.

Lithologic characteristics.—The Byram gneiss shows great variation in composition, texture, and structure. Depending upon the amount of assimilated Pochuck or other earlier pre-Cambrian material, the Byram ranges from its pure form to various types of mixed rocks. The normal texture is average granitic, but finely granitic as well as coarsely granitic facies appear. In many areas the Byram is massive but in other places it has a rude streaking or an indistinct discontinuous banded appearance. Generally speaking, the more common types are those that are massive with slight streaking. The streaks are due to at least two causes. In some outcrops the orientation of the darker mineral particles likely is the result of flow during consolidation of the mass. In other localities the streaks are the remnants of former bands in the Pochuck gneiss, or other formations older than the Byram, in which a planar schistosity had been developed previous to their invasion and assimilation by the Byram. In many places the Byram shows well developed joint sets.

Name and correlation.—The Byram gneiss was named by Spencer [22] from Byram Mountain in New Jersey where the formation is extentively exposed.

In the New Jersey Annual Reports of the 1880s, granitic and quartz syenitic rocks of several types were described. One of these descriptions from the Annual Report of 1886 [23] is as follows:

> Quartz Syenite. This characteristic rock of many Massive areas has been given considerable attention. Thin sections were prepared for microscopical examination by Mr. James F. Kemp, who has furnished the following descriptions of typical specimens:
>
> I. Field No. 234, from a Massive area on the New York and New Jersey State line, between mile-posts 23 and 24, east of Greenwood Lake. The rock consists of Orthoclase, Quartz and Hornblende. The Orthoclase is filled with curious inclusions of irregular prismatic shape, which have optical properties indicating them to be some mineral, and not a glass nor hollow spaces. The Hornblende is very dark colored, and unless ground exceedingly thin, is almost opaque.

It is interesting to note that what was surely the perthitic intergrowth of orthoclase and albite was described but not completely understood.

In the reports of that time the different rock formations often were described without giving them locality names. In the Franklin Furnace folio, Spencer and others used the term Byram gneiss to describe the rocks occurring characteristically in Byram Township, Sussex County, New Jersey. They [24] included

> Several varieties of granitoid gneiss which are lithologically related by the presence of potash bearing feldspars among their principal mineral components. As thus defined, the formation includes the "Hamburg," "Sand Pond," and "Edison" gneisses, which were separately mapped by Wolff[25] in the Franklin Furnace district; the "Oxford type" of gneiss, described by Nason; [26] and the gneissoid granite of Breakneck Mountain, of the Hudson, described by Merrill.[27]

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[22] Spencer, A. C., and others, op. cit., p. 5.

[23] Britton, N. L., op. cit., p. 102.

[24] Spencer, A. C., and others, op. cit., p. 5.

[25] U. S. Geol. Survey, Eighteenth Annual Report, pt. 2, p. 439, 1898.

[26] Annual Report Geol. Survey of New Jersey for 1889, p. 30.

[27] U. S. Geol. Survey Geol. Atlas, New York City folio (No. 83), 1902.

[28] Bayley, W. S., and others, op. cit., p. 70-71.

Bayley[28] discusses the Byram as follows:

> Character and varieties.—The several phases of the Byram gneiss differ greatly in appearance, but as seen in outcrop most of them resemble one another more than they do the Losee or Pochuck gneisses. Of the two principal varieties observed one is dark gray and moderately coarse-grained and has a bronzy-brown tone on freshly fractured surfaces. It is composed essentially of microperthite, microcline, orthoclase, hornblende, quartz, magnetite, and in some places biotite. The dark minerals are ordinarily grouped into pencils arranged parallel to the strike of the rock bands. This grouping produces a gneissoid appearance on all fractured surfaces except that transverse to the axes of the pencils, where the structure appears evenly granular. The axes of the pencils pitch in the same direction as the axes of the ore bodies in the various magnetite mines throughout the region. This structure, which is characteristic of nearly all the gneisses in the district, is known as linear structure. Its strike in the region is generally N. 15-40° E.
>
> The second variety of the rock is yellowish in outcrop, and pink, light gray, or nearly white on fresh fractures. It is ordinarily finer grained than the dark-gray variety, from which it differs mineralogically mainly in the subordination of dark components and thus the rock lacks the pencils of the darker variety and consequently does not show the distinct pitch structure. It may possess a slight linear structure, but as a rule this is so obscure that the texture of the rock is practically granitic.

From a survey of the work of previous students of the pre-Cambrian gneisses of Pennsylvania and New Jersey, it will be noted that the numerous early granitic formations have been grouped under a gradually decreasing number of formational names.

In the present publication, all the granitic rocks characterized by the presence of quartz and alkali feldspar have been mapped as Byram gneiss. This group, therefore, includes that granitic material which is thought to represent the pure Byram made up of quartz, microcline, and microperthite, as well as a large number of variations of this typical material, which changes are for the most part dependent upon varying amounts of material assimilated from the invaded rocks. Under the name Byram has also been included pegmatitic granitic bodies and irregular pegmatitic masses.

The exact age of the Byram gneiss is unknown but it is younger than the Franklin formation, the Moravian Heights formation and the Pochuck gneiss because all these are intruded by granitic material of the Byram. These older formations have been thought to represent the late Archæzoic or Huronian. The Byram granite gneiss shows much less metamorphism than do these older formations. Pegmatitic differentiates of granitic material cutting the older formations and the Byram gneiss indicate either a continued period of pegmatitic emanation or successive periods of such introduced material. With these thoughts in mind, it is suggested that the Byram granitic material is of Proterozoic age with some of the pegmatitic injected material likely of late pre-Cambrian time and some of it in Northampton County definitely post-Hardyston in age. It could, therefore, be correlated with any of several of the Proterozoic intrusive masses found in the pre-Cambrian area of Canada, but there is no definite evidence as to its exact position in the geologic time scale.

Stratigraphic and structural relations.—The general structural relation of the Byram to the other pre-Cambrian formations is one of intrusion and invasion, in part along the previously-formed structural planes of the older formations and in part as cross-cutting masses. The present scattered, and, in general, small areal occurrence of the older formations indicates that erosion following the introduction of the Byram reached to considerable depths. This resulted in the removal of most of the volume of the invaded material and at present the largest part of the area is occupied by Byram with a smaller total area made up of streaks and lenticular remnants of Pochuck gneiss, and the Moravian Heights, and Franklin formation.

Petrography and petrology.—As has been stated, the Byram varies considerably in its composition. The minerals of the facies that is thought to represent the pure type are quartz, microcline, soda microline, microperthite, orthoclase, and small amounts of apatite and magnetite.

Analyses of rocks of the Byram type from Pennsylvania and New Jersey

	1	2	3	4	5
SiO_2	77.07	58.75	61.54	73.64	64.64
Al_2O_3	12.61	17.16	17.98	12.82	15.92
Fe_2O_3	.71	5.18	3.11	.65	1.14
FeO	.73	3.94	3.21	1.55	4.65
MgO	Trace	.91	.32	.12	.23
CaO	.87	.62	2.29	1.08	2.12
Na_2O	3.43	5.72	5.85	2.47	4.38
K_2O	4.06	5.40	4.77	6.22	6.06
H_2O	.23	.35	.09	.14	.04
H_2O+	.62	.73	.78	.68	.43
TiO_2	.12	.65	—	.17	.42
CO_2	Trace	.13	.42	.38	—
P_2O_5	Trace	.20	.18	.04	Trace
MnO	.09	.10	.08	.03	.03
BaO	—	—	—	.04	.10
ZrO_2	—	—	—	—	Trace
S	—	—	—	None	.06
Trace?	100.54	99.84	100.62	100.03	100.22

1, 2, 3, from U. S. Geol. Survey Geologic Atlas, Raritan folio (No. 191), p. 9, 1914, (field edition p. 73). 1. Quarry a mile west of Hibernia. 2, 3. Van Nest tunnel, Delaware, Lackawanna & Western Railroad, near Oxford.

4, 5, from Geology and Mineral Resources of the Quakertown-Doylestown District, Pennsylvania and New Jersey. U. S. Geol. Survey Bull. 828, p. 14, 1931. 4. Quartz monzonite (Byram). West end of Furnace Hill, Boyertown quadrangle, Pa. 5. Quartz monzonite (Byram). South of Ludwigs Corner, Phoenixville quadrangle, Pa.

Other types of the Byram range from the pure original material into facies which include abundant hornblende and plagioclase feldspar commonly of oligoclase or oligoclase-andesine composition. In addition, varieties containing biotite and hornblende with plagioclase feldspar of the more sodic types are found. Magnetite is more abundant in the rocks containing hornblende and often the percentage of apatite also increases. The pegmatitic material associated with the Byram gneiss is typically a quartz, orthoclase or microcline rock.

Pegmatitic Material

Pegmatitic material is often found on hill slopes as float fragments occurring with more abundant blocks of Byram or Pochuck gneiss. Where masses of pegmatite are exposed they commonly show gradational contacts with the intruded formations, and for the most part occur as irregular masses with no definite form.

Lithologic characteristics.—In hand specimen the pegmatitic material varies from coarsely crystalline microcline or (and) orthoclase with associated quartz and hornblende or biotite to types that are essentially pegmatitic granites composed of orthoclase, microcline and quartz with or without smaller amounts of hornblende or biotite. Many of the pegmatites associated with the Pochuck contain oligoclase or oligoclase-andesine in abundance. This material, and the recrystallized hornblende associated with it, has been derived by assimilation from the Pochuck gneiss, and represents a product of intermediate composition.

Age relations.—The intrusive relations of the pegmatites to other formations, including the Byram gneiss, indicate their later age. They are unquestionably to be regarded as having been formed through a great range of time. Some pegmatitic masses were intruded into the Byram and were later eroded to form in part the surface on which Paleozoic rocks were deposited.

Local details.—In the northeast nose of the ridge lying just southwest of Macungie, granitic juices have invaded the Pochuck diorite gneiss and have intimately penetrated this more basic rock. The minerals of the diorite have been attacked and partially absorbed by the invading granitic material, with varying degrees of assimilation.

The invaded rock is in most places made up of hornblende and andesine with occasional grains of magnetite and apatite. In some places both biotite and hornblende are found, but the usual occurrence is the hornblende-rich type in which hornblende makes up somewhat less than half of the volume of the rock. Commonly this rock is gneissic, showing definite streaking due to the concentration of the dark grains, but it may appear in granulose facies, in which the hornblende is more equidimensional than in the gneissic types, and a decussate structure is suggested.

Where the biotite-bearing facies was invaded by granitic material, alteration progressed as follows: Biotite broke down and was largely replaced by zoisite, the fine grains of zoisite retaining the structure of the biotite except where the whole mass has been replaced through assimilation by the granite. In both the biotite-bearing and hornblende-bearing types the andesine shows alteration to both sericite and epidote, which usually occur along the contact of the andesine with the attacking granite minerals, and also may appear throughout the crystal as disseminated flakes and grains without arrangement; or they may be concentrated along twinning planes, or in other grains there may be almost complete sericitization and epidotization. The borders of the attacked grains show a variation from those that have rounded outlines to those that have very irregular, jagged outlines. The former are thought to indicate that the chief action of the invading material was to dissolve the andesine and produce some sericitization of the margin of the attacked grains. The irregular, jagged type of grain outline indicates a more caustic attacking solution. This suggestion is substantiated by the absence of alteration flakes of sericite in the outer zone of these grains. This zone is interpreted as having been formed by the leaching from it of lime, leaving an enriched soda-plagioclase (albite) border to the original andesine grain.

The hornblende-andesine type exhibits similar alteration of the andesine and demonstrates the greater resistance of hornblende over biotite to decomposition by the granite invasion. In a specimen of this facies quartz, orthoclase, and microcline are found throughout the mass as irregular grains penetrating to the interior and replacing along the margins of both hornblende and andesine. The abundance of replacing material varies so that in places the rock appears as a hornblende-andesine diorite with isolated patches of quartz, orthoclase, and microcline while again where greater assimilation has occurred, the main mass may be composed of quartz, orthoclase, and microcline with only remnants of the original more basic rock minerals. In all cases the granite minerals are remarkably fresh and unaltered while andesine invariably shows alteration along the assimilation contact, if not throughout the grain. Where hornblende is in contact with the invading material it is partially dissolved without marked alteration of the remnants.

Grains of sericite, epidote, and zoisite occur as inclusions scattered through some of the quartz and orthoclase grains. These are regarded as having formed by hydrothermal attack on the part of the invading granite. Also, grains of andesine and hornblende larger than those of the diorite and showing less alteration to sericite and epidote, but showing partial replacement are thought to have been formed by the recrystallization of previously assimilated andesine and hornblende. Furthermore, it appears that in some places quartz has encroached on orthoclase and microcline.

In general the sequence of processes is interpreted to be as follows:

1. The granite invaded the diorite and assimilated large quantities of the latter and at the same time spread granite juices throughout the unassimilated diorite, which partly altered andesine, biotite, and hornblende.

2. As the magma with its assimilated dioritic material continued to cool, hornblende and andesine crystallized out.

3. Orthoclase and microcline formed next and in places encroached on and replaced the original andesine.

4. Lastly, quartz crystallized and encroached on andesine, hornblende, and orthoclase.

It appears then that in the case of each successive crystallization product a reaction occurred with the previously-formed minerals, resulting in the partial replacement of the earlier minerals.

GENERAL DESCRIPTION OF THE PALEOZOIC, MESOZOIC AND CENOZOIC ROCKS

By Benjamin L. Miller

The Paleozoic and later rocks of Lehigh County are readily separable from the Proterozoic or pre-Cambrian strata. With the exception of some intrusive basic rocks in the area of Triassic sediments, all are of sedimentary origin and have undergone relatively slight changes, other than cementation and solidification, since their deposition. Metamorphism has taken place to the extent that some of the shales have been converted into slates, some sandstones to quartzites, and some limestones to low-grade marbles, but these are all low-grade metamorphic rocks in comparison with the gneisses and schists of South Mountain and are generally regarded as non-metamorphic or non-crystalline rocks. Lithologic features constitute the principal means for differentiating the formations, but structural relations and, in some cases, fossil remains can also be employed. Microscopic investigations are useful but of less significance than in the pre-Cambrian rocks.

Paleozoic Era

The Paleozoic rocks constitute the major part of the exposed strata of Lehigh County, extending almost uninterruptedly from South Mountain to the northern limits of the county. They are also present as the basement rocks in some of the intermontane valleys situated between ridges of the crystalline rocks in the southern part of the county. During the formation of the Paleozoic rocks an extensive shallow inland sea covered the entire region and extended northeast, northwest, and southwest for hundreds of miles. The land mass which furnished the sediments that now constitute the Cambrian strata lay to the southeast. At times the shore line apparently was not many miles away, but at other times the land mass, which has been called "Appalachia," probably was depressed so that the shore was distant perhaps 50 or more miles.

In age, the Paleozoic strata present in Lehigh County extend from the Lower Cambrian to the basal Silurian. Within this period of time there were some interruptions in deposition, but these were short in comparison with the time when water covered the area and deposition was taking place. The gaps in the sedimentary record were caused by uplifts, lack of deposition, and removal by erosion of certain portions of the previously formed deposits. It is not possible to determine in some cases whether the absence of some beds that are present in other parts of the Appalachian belt is the result of non-deposition or of deposition and subsequent removal before the next strata were deposited. Alternately the region has existed as land and as sea, or at certain periods as areas of construction and at other times of destruction. An enormous amount of erosion has taken place since Silurian time; many thousands of feet of rocks have been carried from southeastern Pennsylvania. It is therefore possible that a large part, or all, of the Silurian, Devonian, Mississippian, and Pennsylvanian formations now present in the regions beyond Kittatinny (Blue)

Mountain once continued over Lehigh County, although at present the upper Paleozoic above the basal Silurian is entirely lacking.

Cambrian system.—Rocks of Cambrian age are extensively developed in the southern portion of Lehigh County. They rest uncomformably upon the basal crystalline rocks of the pre-Cambrian and are much younger. The gap between the youngest of the crystallines and the oldest of the Cambrian represents a great period of time, as yet indeterminate.

As shown in the geologic table on a preceding page, three divisions of the Cambrian are recognized. These are, in order of age, the Hardyston which is almost entirely an arenaceous formation, and the Tomstown and Allentown (Conococheague) which are impure magnesian limestone formations. To the southwest the Cambrian strata have been divided into two more formations which are apparently absent in this area. Overlying the Tomstown in Franklin County there is a series of arenaceous strata, designated as the Waynesboro formation. This formation has no counterpart in the Lehigh Valley. The Waynesboro in that section is overlain by limestones and dolomites known as the Elbrook formation. Both the Waynesboro and the Elbrook have been referred to the Middle Cambrian. In a few localities in this region some magnesian limestones, here included in the Tomstown, present some features similar to some of the Elbrook strata of other regions. This has led some workers to believe that the Elbrook is present in this region and should be differentiated. Any attempt, however, to map a distinct unit as Elbrook in Lehigh County would require the drawing of arbitrary and confusing lines that could not be established on known field evidence either lithologic or paleontologic.

The differentiation of the magnesian limestones of the Cambrian of the Lehigh Valley in some localities is difficult and in certain instances it is impossible to be positive. The criteria for separation are almost entirely lithologic and similar features occur in each of the formations. In small exposures or in hand specimens it is generally impossible to identify the particular formation. Fossils are generally extremely rare. The complexity of structure and the absence of outcropping beds over extensive areas still further complicate the problem.

Dr. John M. Hills[1] studied the insoluble residues of some of the limestones of the Lehigh Valley in an attempt to correlate the strata and interpret the structures. He made a most detailed investigation but was forced to the conclusion "that, while the method of insoluble residues can not be recommended for independent use in regions of complex structure, it is very valuable as an adjunct to conventional field methods in determining stratigraphic succession and establishing more exact lithological correlations." (loc. cit., p. 131.)

Even this cautious statement appears to the writer as perhaps somewhat too optimistic. The shallow-water deposits of the Cambrian limestones of this region present too many local variations for this method to be reliable except in those places where outcrops are abundant, a situation that is rare in this region.

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[1] Hills, John M., The Insoluble Residues of the Cambro-Ordovician Limestones of the Lehigh Valley, Pennsylvania: Jour. of Sedimentary Petrology, vol. 5, pp. 123-132, 1935.

Dr. Hills' contribution to the microscopic constitution of the Lehigh Valley limestones is valuable in the consideration of their origin. Rounded quartz sand grains, light and dark-colored chert and dolocasts are common; angular fragments of quartz and occasional grains of pyrite, garnet, magnetite, and hematite are noted in many specimens. No one of these minerals was found to be diagnostic of any particular formation, so that correlations were based on their relative abundance. In addition, Dr. Hills found some microscopic foraminifera as had B. Frank Buie previously while engaged in the study of insoluble residues of the Allentown formation.

Ordovician system.—The Ordovician rocks overlying the Cambrian strata are readily differentiated in most places, but are similar in many respects, as the same general physical conditions prevailed. Until rather recently the separation of the Cambrian and Ordovician in the Appalachian region was not made. The uppermost Cambrian and lowermost Ordovician are prevailingly calcareous deposits and were mapped as the Cambro-Ordovician limestones. In Pennsylvania and Maryland they were called the Shenandoah Limestone and in New Jersey the Kittatinny Limestone.

As in the case of the Cambrian, the Ordovician of the region is now divided into three formations, Beekmantown, Jacksonburg, and Martinsburg. In a general way these represent a progressive change in the character of the sediments from calcareous to argillaceous and arenaceous.

The Beekmantown is composed almost entirely of limestones; the Jacksonburg, composed of argillaceous limestones, represents a transition phase between limestone and shale; and the Martinsburg is composed almost entirely of shales with some sandstones, a still further change in the same direction. Fossils are more abundant in the Ordovician deposits than in the Cambrian, although still scarce in comparison with rocks of the same age in some other parts of the country or with some of the younger Paleozoic rocks of the State.

Silurian system.—As stated previously, the Silurian rocks of Lehigh County are confined to Kittatinny (Blue) Mountain. They rest unconformably on the uppermost Ordovician present in this section and are so distinct in their lithologic constitution that it is possible to draw a sharp line of separation wherever exposed. Fossils are rare but are not needed for differentiation. All of the Silurian strata of the county belong to a single formation, the Tuscarora.

Mesozoic Era

There is an enormous gap in the sedimentation record of Lehigh County between the Tuscarora of Kittatinny (Blue) Mountain and the next rocks. This time interval has been estimated at about 200 million years. Great thicknesses of sediments were accumulated in other regions and then came the great Appalachian Revolution that compressed, folded, and faulted the pre-existent rocks into the complicated structures that are readily apparent everywhere in the county.

When sedimentation was resumed in the early part of the Mesozoic it was confined to a small part of the Appalachian belt. In Lehigh

County only the extreme southern portion was under water. The prevailing red colors of the shales and sandstones, and the absence of folds, sharply separate these strata from the much older beds on which they rest unconformably.

Triassic system.—All of the Mesozoic strata of Lehigh County belong to the Brunswick formation, the youngest member of the Triassic system. In fact only a small part of that formation is represented. The full thickness of the Brunswick and of two earlier Triassic formations is present in Bucks County.

Closely associated with the Brunswick shales and sandstones are several intrusions of igneous rock. Owing to their relatively great resistance to erosion the outcrops of these sheets of trap rocks form conspicuous elevations in the topography.

Cenozoic Era

Another long-time gap intervenes between the Brunswick and the next oldest rocks. The time interval has been estimated to be about 150 million years. So far as is now known the region during all of this time was undergoing erosion. If deposits were formed, they have since been carried away by the transporting agents of running water and wind.

Pleistocene period, Glacial epoch.—The invasion of the Lehigh Valley by the advanced tongue of an ice sheet resulted in the deposition of a thin discontinuous mantle of unconsolidated boulders, sands, and clays. The ice dropped some of its burden where it melted; other portions of the debris which it carried were transported somewhat further by the water resulting from the melting of the ice.

Altogether the deposits of this period are insignificant in comparison with the older formations of the county. The deposits at most are only a few tens of feet thick and generally only a few feet, and the time of deposition is measured by thousands instead of millions of years.

Recent Era

Some thousands of years have elapsed since the disappearance of the glacial ice. Since that time erosion has been active, and deposition of minor importance. There has been an accumulation of residual debris in the limestone areas where the soluble portions have been carried away in solution, leaving the insoluble material. On the lower slopes of the prominent elevations such as the ridges of South Mountain and Kittatinny (Blue) Mountain great talus heaps have formed. And, finally, alluvial material has accumulated in the channels and along the flood plains of the streams. The processes responsible for these Recent deposits are still in progress.

With the above generalized description of the post-Proterozoic rocks of Lehigh County, the detailed descriptions of the separate formations naturally follow. These are taken up in sequence in order of age by the different authors responsible for them.

The descriptions of distribution are based on the accompanying geologic map. The absence of exposures in certain regions requires the arbitrary location of some of the formation lines, but this can not be avoided. With the incomplete data it must be recognized that no two persons working independently will have any more than partial agreement in certain sections. If and when new maps are prepared by other observers it must be expected that numerous disagreements will be noted. In no case should the later map invalidate the former unless more data have become available or a more correct conception of the structural conditions has been formulated.

CAMBRIAN SYSTEM

HARDYSTON FORMATION *

By Benjamin L. Miller and Philip B. Myers

Distribution.—A generalized statement with only a few minor exceptions is that Hardyston strata crop out in a narrow band on the comparatively steep slopes of the gneiss hills, generally near the base although in a few places extending to the crest of the hills. In the latter instance, the dip is practically the same as the slope of the hill so that the Hardyston forms a thin cover to the hill. Generally, however, the strata dip at considerably greater angles than the slope of the hill so that the width of the outcrop is not greatly in excess of the thickness of the formation. The greater resistance to erosion, as compared with the overlying limestones, is responsible for the beds cropping out at higher levels than the limestones. In many places numerous blocks of Hardyston have moved down the slopes and now rest on the limestones considerable distances from the outcrop of the rock in place. Similarly the Hardyston outcrop is commonly concealed by the gneiss talus from the higher portions of the hills. A rule that in general is satisfactory is to draw the contact of the Hardyston and gneiss at or somewhat above the place where the last piece of the Hardyston is noted as one ascends the hill and to draw the Hardyston and Tomstown contact at or near the point where the slope of the hill changes or where sinks appear as one descends the hill. Since talus so generally conceals the outcrops these somewhat inexact methods must be used in mapping.

Normally, the Hardyston should crop out everywhere between the pre-Cambrian crystalline formations and the Tomstown but in several places no evidence of its existence can be found. In the absence of exposed sections from the gneiss to the limestone, it is necessary to choose between three explanations. (1) The formation is present but thoroughly concealed by talus and soil. (2) Faulting has occurred by which the gneiss and limestones have been brought into contact. (3) No deposit was formed at that particular place or it was entirely removed by erosion before the deposition of the Tomstown. Differences of opinion are bound to result and no one's work should, therefore, be discredited on that score. The present investigators have mapped the Hardyston only in those places where some positive evidence has been obtained. If the evidence is only that of loose fragments of rock in the surface soil, an uncertainty sometimes prevails in that the Hardyston presents a great variety of lithologic phases, some of which are indistinguishable from similar features of the Silurian and Devonian sandstone and quartzite boulders brought into the region by the glaciers during the Pleistocene period. In general, the glacial cobbles and boulders are more rounded or faceted but not in every case.

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* The senior author began his study of the Hardyston formation in 1907 and has continued it ever since. Recognizing that a further investigation was desirable, Philip B. Myers, while holding a Research Fellowship in the Department of Geology of Lehigh University from 1932 to 1934, was assigned this problem. He has remapped the outcrops of the formation throughout Lehigh County and with slight modification the lines of this formation appearing on the accompanying map represent his conclusions. The following descriptions are in large measure abstracted from his unpublished dissertation, especially that portion entitled Local Details, but modified sufficiently to conform to the treatment of discussion of other formations. Mention should be made of the assistance rendered by Dr. D. M. Fraser in the microscopic investigation.

F. Prime's maps (1878 and 1883) show much more Hardyston than the maps of the authors. Only in a few instances has he mapped gneiss and limestone in contact, whereas the present mapping shows numerous instances where the Hardyston is lacking. In some cases Prime has shown Potsdam (Hardyston) where it is now definitely known that limestones or gneisses are present. Also, in general, he shows a wider band of outcropping sandstone than is now represented. Fountain Hill may be cited as one place where Prime's maps are in error. He shows this hill as sandstone. Outcrops of limestone occur on the crest of the hill as well as on the slopes. There are other similar errors. However, Prime's maps were largely of the reconnaissance character and should not be too severely criticized.

George W. Stose and Anna Jonas Stose have presented maps with much less Hardyston than is shown on our map. Lantern slides of some of their recent maps were shown at the meeting of Section E of the American Association for the Advancement of Science in Philadelphia on December 28, 1940, in which the areas of Hardyston were extremely restricted. The maps have not been made available to the writers for examination and comparison, but the projected slides showed the omission of several areas where it is believed there is abundant evidence for mapping Hardyston.

It should be recognized that some of the disagreements in the mapping of the Hardyston are entirely due to the comparatively few outcrops. As new information becomes available the location of the boundary lines can be more exactly determined.

The Hardyston exposures are confined to the southern townships,—Hanover, Salisbury, Upper Saucon, Lower Macungie, Upper Milford, and Lower Milford. The strata dip northward beneath the limestones and presumably underlie all the limestones and shales of the younger sedimentary formations although at such depths that they have not been reached by any deep drilling.

Lithologic characteristics.—The Hardyston in Lehigh County presents more varied lithologic features than any of the other sedimentary formations. This variability occurs not only in the vertical range of the beds but also along the strike and in very short distances. In many cases certain of these characteristics are peculiar to only one or a few local outcrops.

From an early date, when the formation was designated as the Potsdam, to the present, it has been more or less customary to speak of the whole formation as Hardyston (Potsdam) quartzite. Such a designation is distinctly inaccurate since we have learned that true quartzite constitutes only a minor part of the formation. Instead, it contains conglomerates, sandstones, quartzites, jasper, chert, shales and locally a micaceous material that has been called pinite.

Conglomerates.—At or near the base of the Hardyston formation there is generally a coarse conglomerate. It is composed of well-rounded quartz pebbles, often lightly stained to a wine-red color. These pebbles are cemented in a dark quartzose matrix. This matrix contains some epidote, chlorite and detrital heavy minerals. The size of the quartz pebbles ranges from one-quarter inch to four inches in diameter, even the largest being well rounded. The color of the matrix varies somewhat, but usually it is dark. At no exposure in Lehigh County does the thickness of this member exceed eight to ten feet.

Quartzite and sandstone.—The sandstones and quartzites are not discussed separately as they grade into each other so thoroughly that no sharp distinction can be made. There are two common varieties,—the arkosic and the non-arkosic.

The non-arkosic quartzitic variety is less abundant. In a hand specimen it is commonly bluish gray, gray or white whereas the arkosic varieties are generally buff or salmon-colored. Most of the occurrences show a fine-grained, fairly homogeneous rock that breaks readily under the blow of the hammer, almost like glass, and produces conchoidal fractures. Pebbles or sand grains are not readily observable by the naked eye.

Under the microscope in thin section the rock is seen to be composed of a mosaic of interlocking quartz grains which reveal secondary enlargement of rounded quartz particles. Impurities, such as iron oxide, are confined chiefly to the present grain boundaries although in some cases they surround the original sand grains.

The most typical phase of the Hardyston formation is an arkosic sandstone. This rock is buff, salmon-colored, or white, depending upon the amount and condition of the feldspar, or arkose. Blue and gray rounded quartz grains make up most of the rock. In the typical building stone variety of arkosic sandstone the quartz grains are between one and three millimeters in diameter, but a pleasing irregularity is caused by scattered larger grains, seldom larger than one centimeter. The feldspar often is quite fresh, but more generally is altered to kaolin or sericite. The fracture of the rock is rough, giving it a massive appearance which further adds to its attractiveness as a building stone.

The arkosic sandstone beds of the Hardyston, where exposed, usually run from the basal phase to the erosion surface. This fact is easily accounted for when one considers that nearly all the exposures are in quarries, and that these openings would naturally start where good building stone cropped out, and extend as deep as there was workable stone, which would usually end at the top of the basal phase. At no place have the authors seen an upper contact of the arkosic sandstone. It may grade into the limestones, but the upper contact apparently is covered with talus and soil, so that the sequence is unknown. For the same reason the thickness of the phase can only be estimated. In various quarries the thickness of the exposed arkosic sandstone is up to 60 or 75 feet. The total thickness of the phase may be 125 feet in places.

The arkosic sandstone in thin section shows the chief mineral to be quartz. Most of the quartz grains are less rounded than in the true quartzite. The presence of arkosic material suggests that at least some of the quartz must have had little chance to become well rounded. Some secondary enlargement of the quartz grains has occurred, but there is also much sericitization in the binding material. The feldspars are remarkably fresh in thin section, being mainly microcline, soda microcline, and microperthite. These minerals show some alteration to sericite. Euhedral grains of pyrite are disseminated through most specimens of the rock. A few grains of zircon are scattered through the sericitic matrix.

The arkosic sandstone that contains the *Scolithus linearis* horizon appears to be the same as the ordinary rock in respect to mineral content and microscopic appearance. The grains of opaque minerals are more numerous in the tubes than in the host rock, or vice versa. No other unusual microscopic characteristic is present.

Jasper.—Throughout Lehigh and Northampton Counties the Hardyston formation has local occurrences of jasper. Although the jasper is generally found as float, there is at least one locality, west of the Allentown-Philadelphia highway, south of Mountainville, Lehigh County, where it crops out as massive beds in the stratigraphic position of the Hardyston (pl. 15A).

The jasper of the Hardyston is taffy yellow to dark brown, or red. It is fine-grained, having a satin-like surface when very fine, and a fine sandy surface when coarse. The fracture varies from perfect conchoidal to rough. The rock is often a breccia which has been recemented by silica in the forms of chalcedony and quartz.

The jasper does not seem to occur at any definite horizon in the Hardyston, nor is it usually persistent for any great distance along the strike. One fact is generally true, namely, that the jasper phase is closely associated with the iron-ore phase. In nearly every old iron mine there are many blocks of jasper. The limonitic iron ore must be closely related to the jaspers in origin.

At several localities in Bucks, Berks, and Lehigh Counties, jasper pits were worked by the Indians, who there obtained their stone for weapons and implements. At Vera Cruz rather extensive openings were made. Large amounts of jasper chips are lying in the fields nearby, but few actual arrowheads or implements have been found. Presumably the Indians roughed out their weapons here, to make transportation easier. The fine dense jasper probably was very much sought for by the Indians, and the pits probably were carefully guarded by the tribes.

Myers [1] and Fraser [2] have made detailed microscopic examination of the jaspers of the region. The following paragraphs are quoted from Fraser's article:

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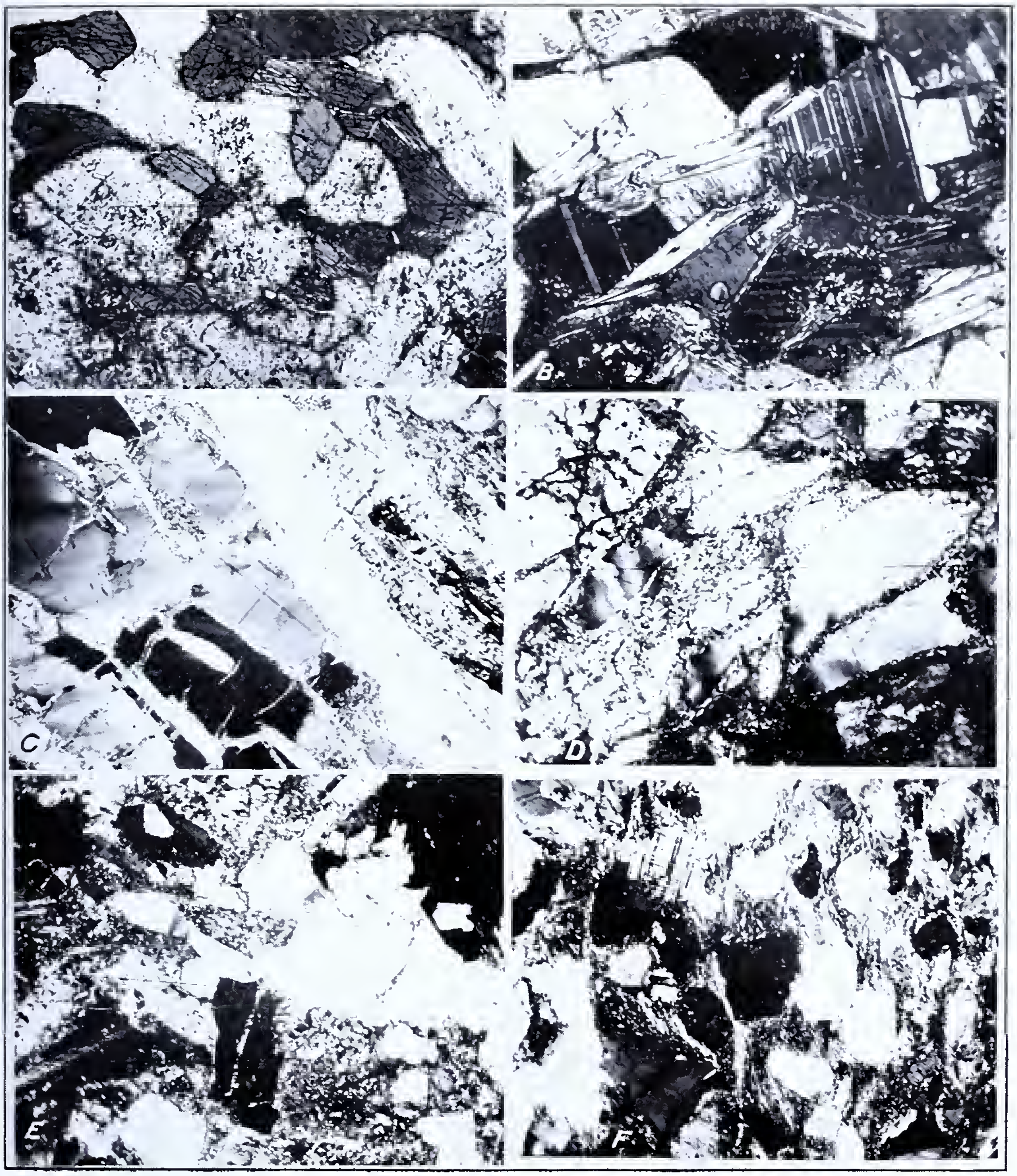
[1] Myers, P. B., The Origin of Jaspers in Lehigh and Northampton Counties, Pennsylvania: Pa. Acad. Sci. Proc., vol. 8, pp. 87-92, 1934.

[2] Fraser, D. M., Replacement of Hardyston Quartzite by Jasper: Pa. Acad. Sci. Proc., vol. 11, pp. 57-61, 1937.



Photomicrographs of Cambrian and pre-Cambrian rocks.

A. Photomicrograph of Pochuck gneiss. This is the hornblende-andesine type of Pochuck. The darker grains are hornblende; the lighter areas are andesine showing partial alteration to epidote and sericitic material.

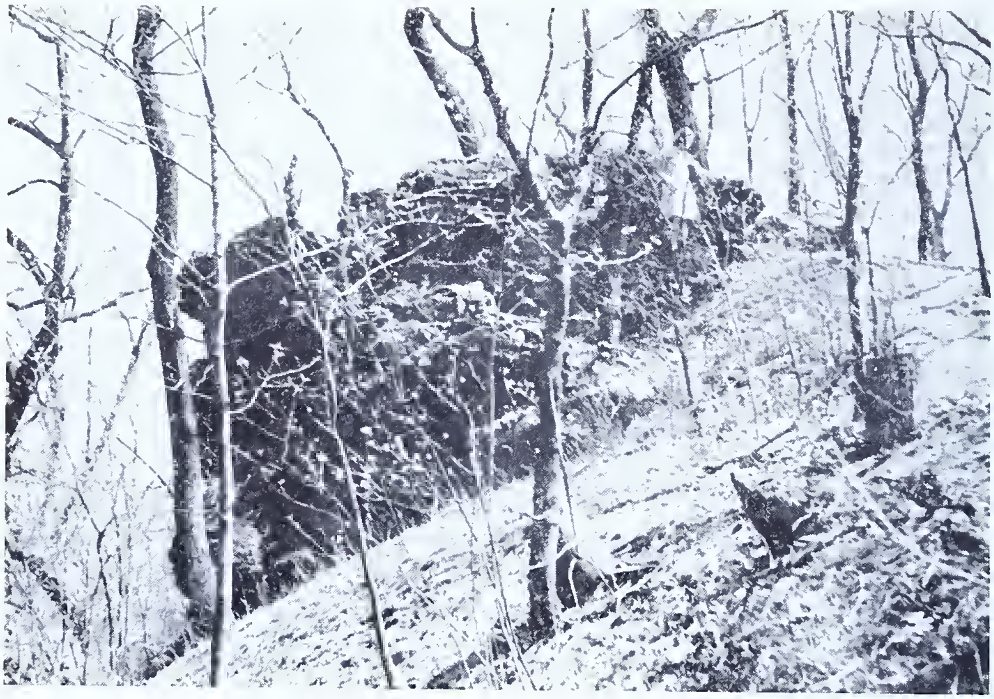
B. Photomicrograph of gradational material between Pochuck and Byram. The bladed crystals are biotite and the crystals showing twinning are oligoclase-andesine. This material represents the type of rock produced from the crystallization of Byram that has assimilated some Pochuck.

C. Photomicrograph of Moravian Heights formation. The larger areas at extinction and partial extinction in the left hand part of the view are quartz. Embedded in the quartz are some elongate areas of sericite marking the former existence of sillimanite. The less distinct material in the right hand part of the view shows sericite developing from sillimanite of which only small remnants are observed. It is the sericitic zones in this rock that make the greenish serpentine-like bands in the hand specimen.

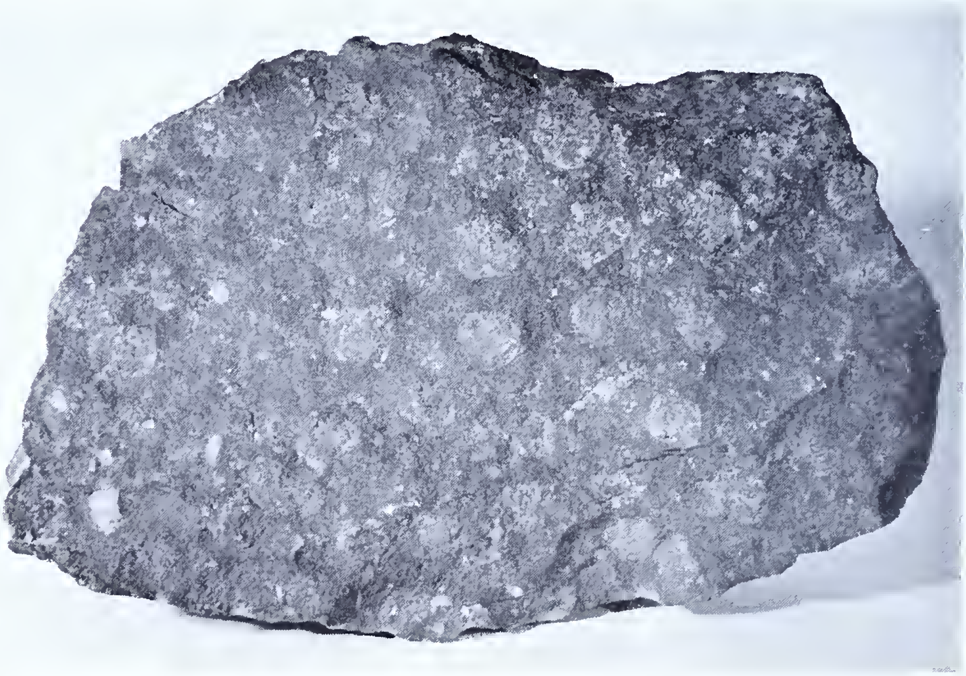
D. Photomicrograph of Byram gneiss showing numerous close-spaced crushed zones. The material in the upper and upper left part of the view is microcline. The larger areas showing numerous small mylonitic bands in the central part of the picture are quartz.

E. Photomicrograph of metabasalt. The large white area in the right hand part of the view is pyroxene. Surrounding it is sausserite produced from the breakdown of andesine labradorite. The larger opaque grain in the lower center is magnetite. These rocks are typically highly altered and for the most part are now greenstones.

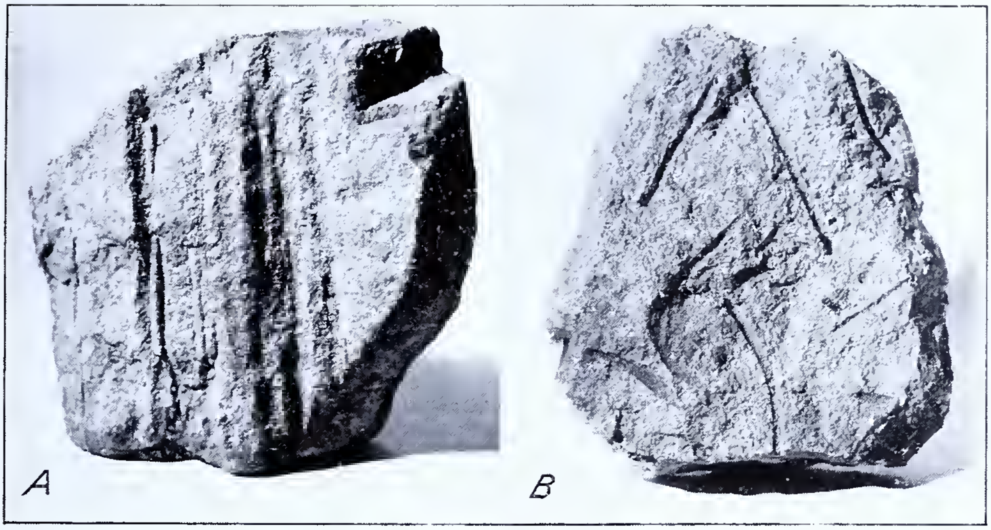
F. Photomicrograph of Hardyston quartzite showing the extensive sericitization of the cementing material and of the feldspar grains. This indicates the action of hydrothermal solutions which are thought to have been introduced from some igneous source not now exposed at the surface but of post-Hardyston age.



A. Jasper cliff west of Mountainville on slope of South Mountain.

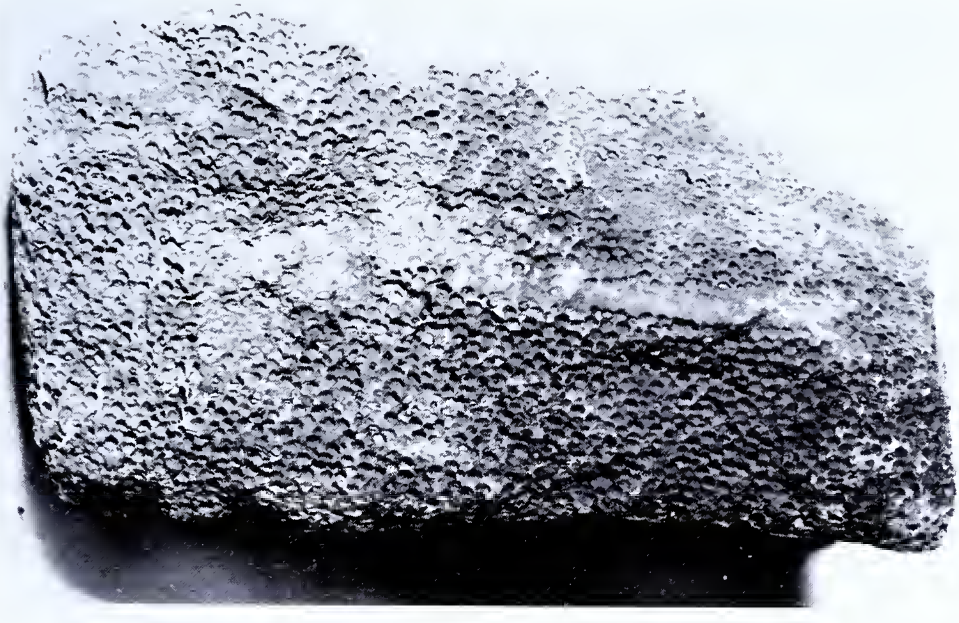


B. Large size *Scolithus.* Hardyston sandstone quarry north side of South Mountain between Bethlehem and Allentown, south of Lehigh River.

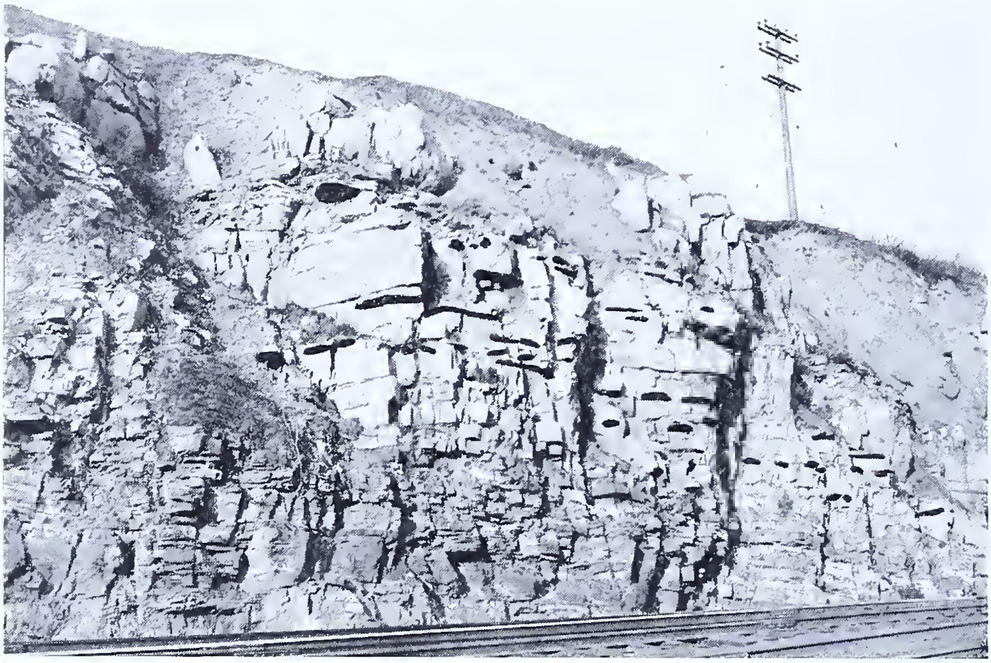


A. Common form of *Scolithus linearis.* Hardyston formation in southwestern part of Lehigh County.

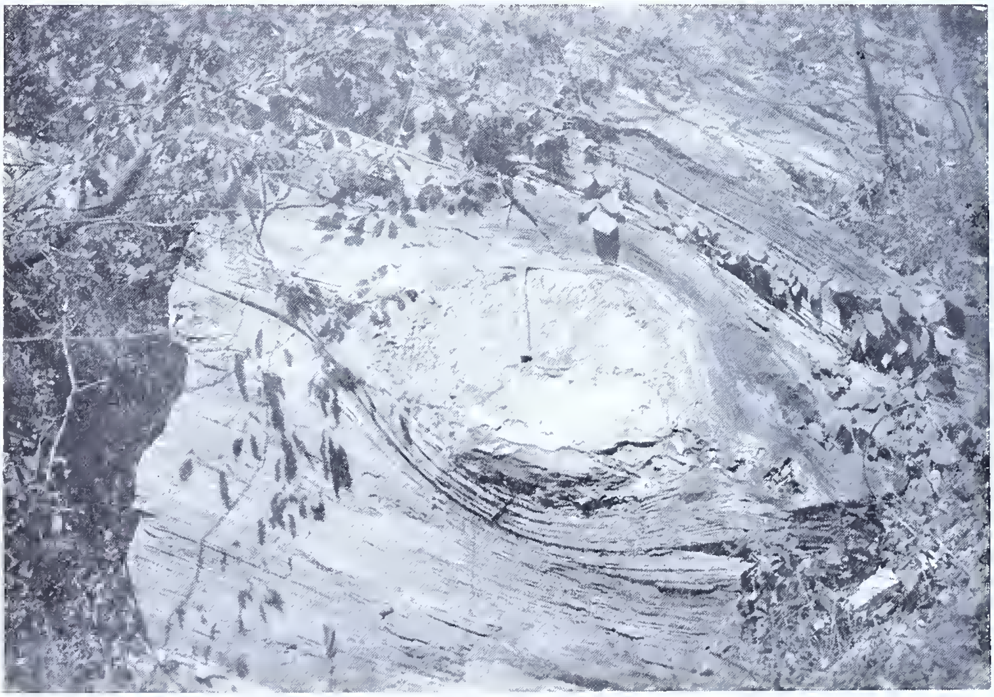
B. Irregular type of *Scolithus*, Hardyston formation. One and one-half miles southeast of Gauff Hill, Northampton County within one-fourth mile of Lehigh County line.



C. Coarse oolite in Tomstown dolomitic limestones, East Allentown. Many of the spherules have weathered out, leaving round cavities.



A. Thin shaly and thick dolomitic limestones of the Tomstown formation. Along Central of New Jersey Railroad West Bethlehem. The blackened lenses are black flint segregations.



B. Layer of dolomite between two low-magnesian beds has been squeezed into a string of nodular-like masses of which one is shown. The weak low-magnesian beds by flowage wrap around the nodules. Beekmantown formation, one mile east of Guthsville.

That the Hardyston has been altered to jasper or ferruginous chert in many places has been contended by B. L. Miller, who for many years has been guided in part by these materials in tracing the Hardyston in the area. P. B. Myers' study of the Hardyston quartzite in Lehigh and Northampton counties also showed the close association in the field between the jasper and the quartzite. He found and described arkosic facies of the Hardyston showing silicification in the form of encroachment of small microcrystalline areas of silica into both quartz and feldspar grains in the quartzite.

An especially good example of the formation of jasper and ferruginous chert by the complete replacement or reorganization of Hardyston quartzite was found by Robert D. Butler and the writer one and three-quarters miles north of Limeport in the southwest part of the Allentown quadrangle. Small indistinct rounded patches on the surface indicate the former sand grain areas and show definitely that here is a piece of Hardyston quartzite which has been jasperized.

The true nature of this alteration is well shown in thin-section. The rounded grains of the material appear as grains of quartz in the thin-sections. They are typically rounded sand grains firmly cemented together to form a dense quartzite. The cementing material contains small amounts of sericite and (or) chlorite and iron hydroxide granules. In plane polarized light the material appears to be a normal quartzite but when the nicols are crossed the true cherty or jaspery nature of the mass is immediately apparent. The supposed large rounded quartz grains are made up of hundreds of minute granules of silica, the typical crypto- or microcrystalline silica of a silicified rock.

The minute granular nature cannot be related to crushing because the rounded outlines of the larger grain-areas would have been distorted. The suggestion that the original sand grains may have been chert particles is disproved by the close relationship between the small silica granules of the grain areas and those of the matrix or cementing material. Those of the latter area are somewhat larger in places and this feature together with the greater abundance of iron hydroxide in the cementing material serves to outline the sand grain areas both in plane polarized light and between crossed nicols. The fact that some of the thin-sections show a gradation into ordinary ferruginous chert completely lacking in sand grain structure also indicates a later replacement origin rather than a primary deposition of the rounded grains as chert particles. It is thought therefore that there is little doubt that the origin must be one of complete replacement or at least reorganization of the original siliceous rock by iron-bearing siliceous waters.

In many places in the field large amounts of massive jasper or ferruginous chert associated with the Hardyston, bear no trace of the former sandstone structure of the original formation. These areas illustrate the gross replacement wherein masses of the Hardyston were replaced by colloidal silica which later crystallized. Another type of replacement is that wherein the process occurs on a more minute scale in which original structures are preserved. Here, too, the secondary silica is probably deposited in colloidal form, producing a gel which later crystallizes. It is this latter type of jasper or ferruginous chert which is of special importance in the conclusions listed below.

1. Silica-bearing waters have widely permeated the lower Paleozoic sandstone and limestone of the eastern Pennsylvania Highlands.
2. Chert and jasper have been formed in places by the replacement of limestone by the silica in these waters.
3. Jasper and ferruginous chert have been formed in many places by the replacement of the Hardyston quartzite by these waters.
4. The mapping of areas wherein jasper and ferruginous chert are found might be carried out on the basis of the following suggestions:
    a. In known limestone areas the presence of jasper and ferruginous chert may be considered as having been formed by replacement of the limestone.

> b. Where the areas of these materials are in structural continuity with the Hardyston, are found together with the Hardyston, or are on the higher slopes or tops of pre-Cambrian hills they should be considered as having been formed by replacement of the Hardyston.

The above quotation clearly shows that some of the jasper associated with the iron ore has been formed by the replacement of quartz of the sandstone. However, recent observations seem to indicate that most of the jasper has been formed by segregation of silica as replacements of part of the argillaceous beds that overlie conformably the basal sandstones. Between Mountainville and Emmaus the jasper seems rather definitely to overlie the main sandstone beds. Some large masses of jasper are in place only a few feet from the sandstone. The sandstone beds dip beneath the jasper masses, in which stratification lines have been mainly obliterated.

The nearest approach to an exposure of any of the argillaceous beds is seen in a sandstone quarry northeast of Hellertown, Northampton County. The strata are weathered and porous, which seems to indicate that some soluble material has been removed. It may well be that the slates or shales were originally calcareous and similar to those calcareous shales of New Jersey described below. At the same time that underground water removed some of the material from the shales, or later, the jasper and iron minerals were segregated.

George W. Stose and Anna Jonas Stose believe that the jasper was formed by the replacement of limestones at the base of a great overthrust block that pushed great masses of gneiss over the limestones. This theory seems untenable as will be discussed in the chapter on Structure.

Shales.—In scores of places limonite iron ore has been mined in the past from the Hardyston, as will be described in a later chapter. The ore was generally found in a matrix of yellow, red, white or black clay. An examination of numerous old mine dumps reveals many angular blocks of jasper, ferruginous chert and occasional sandstones. The occurrence leads to the conclusion that the ore bodies lie within this formation and it, therefore, is necessary to account for the origin of the clay. The siliceous types of rocks described above can not have been the source of the clay so it seems necessary to assume that the Hardyston contains much shale, especially in the upper portion, although the writers have never seen any development of shale in the formation in this region such as must have been present to explain the large deposits of clay. An exposure of calcareous shale near the top of the formation is reported in the bed of a brook near the old Thatcher Mine east of Stewartsville, N. J.

H. M. Chance (1908), who operated some of the mountain-side iron ore mines more than 20 years earlier, drew two sections illustrating the occurrence of the ore. He showed a thickness of about 150 feet of sandstone overlain by about 450 feet of slate. Within a depth of 100 to 300 feet from the surface the slate has changed to clay. The ore is represented as occurring in definite layers roughly parallel to the bedding of both the sandstones and the overlying unaltered slates. Since Chance had opportunities to see the deposits in place, a situation that no longer exists, it seems that his sections may be relied upon as presenting the true relationships, even though some theories proposed in his article be not accepted.

Judging from the sandstone and chert or jasper thrown out in the operation of the mines, there must have been chert and sandstones interbedded with the slates. Every gradation can be found from the chert with only enough iron present to color it a ferruginous yellow to limonite iron ore with only a small amount of silica.

Although Chance seems to imply that ''slates'' overlie the sandstones either as a normal or universal occurrence, the fact that both jasper and iron ores at this horizon are sporadic indicates that the argillaceous beds were lenticular, extending to variable distances along the strike, and absent in most places.

Since the overlying Tomstown contains numerous shale beds or lenses and its contact with the Hardyston is everywhere concealed where ores have been mined, it has appealed to some people to assign all the ''mountain ore'' limonite bodies to the Tomstown. The association with undoubted Hardyston and the characteristics of the ore do not seem to support this view, although it may well be that in some cases the mines shown on the map as included in the Hardyston may more properly be assigned to the Tomstown.

Pinite.—In several localities a peculiar soft, dense, light-green rock is present which is structureless to the naked eye and has been designated as pinite. It occurs only at the base of the Hardyston. Under the microscope it is found to be composed mainly of sericite mica but with smaller amounts of quartz, epidote and chlorite. In a few places it has been colored red by iron oxide. Fragments of quartz and a lamination parallel to the contact with the surface of the underlying gneiss are occasionally noted, both of which were probably developed by slipping during periods of folding. Rarely the pinite contains some rounded water-worn pebbles. This type of rock has not been seen at any other horizon. It is believed to have been made by the metamorphism of an old residual gneiss soil that was formed before the deposition of the Hardyston and not destroyed by the waves of the advancing sea at the time of submergence of the region in Lower Cambrian time.

Exposures of pinite occur in several quarries along the north side of the mountain between Fountain Hill and Allentown and in a few other places.

Paleontologic characteristics.—The arkosic quartzitic phase contains the only fossil record yet described in the Hardyston of eastern Pennsylvania. *Olenellus* has been found in the New Jersey Hardyston, but thus far no trilobites have been discovered locally. The only feature that may be ascribed to marine life is *Scolithus linearis,* or ''worm borings.'' Throughout a thickness of a few feet, and occurring rather widely as a distinct layer, there is a quartzite which contains long narrow cylinders, filled with material of a different color from that of the bed. Some of these tubes are a foot in length. They range in width from about one-eighth to half an inch. They were recognized by the first geologists of the region as distinctive of the Hardyston (Potsdam of that time) formation. The tremendous number of tubes makes it a bit difficult to believe that they could have been formed by worms and then be filled uniformly with a different colored sand.

However, the worm burrow theory is the only one that seems at all plausible.

Three distinct types of these tubes have been found in the region (pls. 15, 16). They were described by the senior writer in Vol. XIII of the Pennsylvania Academy of Science in 1939. The following paragraphs are quoted:

> The writer has long studied the Hardyston strata, especially in the Pennsylvania counties of Northampton, Lehigh and Berks, and has reached the conclusion that the formation is extremely variable in both constitution and thickness from place to place. His experience leads to an opinion at variance with that expressed by Stose and Jonas[1] who claim that the formation is so regularly divided into three divisions that this character can be used in making structural interpretations. They say that "the upper part is thinner bedded, finely feldspathic, and contains *Scolithus linearis*." In certain places this is true but in other places careful search has failed to discover any specimens. *Scolithus* tubes are abundant in several places in the northwest part of Berks County and the southwest part of Lehigh County but throughout Northampton County it is rarely found and apparently entirely absent in many localities.
>
> Up to date all specimens of *Scolithus* described from Pennsylvania, so far as known, are of the type shown in Plate 16, A. The filled tubes are uniformly about one-eighth inch in diameter, are remarkably straight and at right angles to the bedding planes of the sandstone. Some rocks a foot in diameter may contain a score or more of these filled tubes.
>
> About 20 years ago the writer discovered a new variety of filled tubes in some quarries in the Hardyston sandstone on the north side of South Mountain close to the Lehigh River road between Bethlehem and Allentown. The tubes are almost exactly one-half inch in diameter, are uniformly parallel and vary little in either shape or size. A rock studded with these tubes is shown in Plate 15, B. No specimens of the ordinary *Scolithus linearis* have been found in the locality. Later similar specimens of the same sort were found about one mile southeast of Hellertown, Northampton County and on almost the crest of South Mountain about one mile north of Vera Cruz, Lehigh County. In the latter place the tubes have been distorted by pressure and the cross sections are oval instead of round.
>
> A few months ago still another type of tubes (pl. 16, B) has been found in the Hardyston sandstone a short distance west of Seidersville, Northampton County. The tubes in the specimen are about the same size as those of the ordinary *Scolithus linearis* and are not filled. They differ most in that they show no parallelism of arrangement and many are prominently curved although most of them are straight. As indicated in the cut, which shows an upper surface, the tubes run in every direction. Those at an angle to the surface appear as small holes and are not readily discernible in the illustration. So far this type has been found in only the one place mentioned.
>
> In view of the fact that the early descriptions of *Scolithus linearis* mention the range of diameter of the tubes of one-eighth to one-half inch it seems inadvisable to give a new name to the second type described. However, since no intermediate sizes have been found in the Pennsylvania localities studied it may be useful to designate the two as the large and the small types.
>
> No descriptions known seem to fit the third type and yet the writer does not desire at this time to propose a new name for a fossil whose real character is so poorly known. It is hoped that additional specimens of this type may be discovered.

Thickness.—The base of the Hardyston has been seen in several places in Lehigh County, but nowhere has the upper boundary been observed. Under these conditions no figures of thickness can be given. The sandstone beds aggregate 50 to 100 feet or more. The thickness of the argillaceous beds is indeterminate. Probably 0 to 200 feet is as good an estimation as can be made with existing information.

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[1] George W. Stose and Anna I. Jonas: Geol. Soc. Am. Bull., vol. 46, pp. 760 and 2039, 1935.

Name and correlation.—In the Second Annual Report of Rogers in 1838, he described the Hardyston as his Formation No. 1 of his Secondary rocks. Later he designated it as the Primal White Sandstone and correlated it with the Potsdam Sandstone of New York. While Prime was investigating the geology of the Lehigh Valley for the Second Geological Survey, the name Potsdam was continued. When later several paleontologists and stratigraphers proved conclusively that the Potsdam of New York is Upper Cambrian in age and is underlain by a great thickness of limestones, shales and quartzites of Paleozoic age it became apparent that the Pennsylvania and New Jersey basal Cambrian siliceous deposits should not be correlated with the Potsdam of New York but rather with the Poughquag quartzite of the Taconian (Georgian) series.

Wolff and Brooks [2] proposed the name Hardistonville in 1897, from Hardistonville, N. J. This name was slightly modified by Kümmel and Weller [3] who proposed the shorter township name of Hardiston (later changed to Hardyston) which has since been widely adopted. Even yet, however, one finds the occasional use of the name Potsdam.

The Hardyston of Lehigh County is correlated with the Chickies formation of Chester and Lancaster counties, and with the Antietam sandstone of Franklin County, Pennsylvania.

Stratigraphic relations.—The Hardyston rests unconformably upon the older pre-Cambrian crystalline gneisses. Some of the earlier workers confused banding of the gneisses with bedding planes and announced the conformability of the two classes of rock. It is evident that there was a long interval of erosion between the deposition of the basal Hardyston and the solidification of the underlying igneous rocks.

Presumably, the Hardyston is overlain conformably by the Tomstown formation although no exposure of that contact is known within either Northampton or Lehigh County. Where strata of the two formations are seen in proximity, the close parallelism of strike and outcrop suggest conformability.

LOCAL DETAILS

Rittersville Hill.—The only exposures of the Hardyston formation in this county north of the Lehigh River are on the northern and western slopes of Rittersville Hill between West Bethlehem and East Allentown. The most easterly exposures are in a small ravine a short distance to the north of the roundhouse of the Central of New Jersey R. R. The rock is a fine-grained, dense, gray quartzite. A few layers are slightly pebbly. About 12 feet of beds are exposed with strike N.84°W., dip 34°NE. There has been considerable faulting here as decomposed shaly Tomstown limestone occurs in the ravine to the south resting on sheared Byram gneiss. Some of the quartzite beds show fine slickensides.

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[2] Wolff, J. E., and Brooks, A. H., Age of the Franklin White Limestone of Sussex County: U. S. Geol. Survey, 18th Ann. Rept., pt. II, pp. 431-457, 1898.

[3] Kümmel, H. B., and Weller, Stuart, Paleozoic Limestones of the Kittatinny Valley, New Jersey: Geol. Soc. Am. Bull., vol. 12, pp. 147-161, 1901.

Continuing westward the Hardyston can be traced by loose pieces to the southeast corner of Central Park, where a white conglomerate crops out. The quartz pebbles range in size up to three-fourths of an inch. Through Central Park the sandstone crops out almost at the crest of the ridge.

In the grounds of the Allentown State Hospital a small amount of Hardyston sandstone was once quarried.

The sandstone wraps around the west nose of the hill in East Allentown. Some good building stone was obtained here. The gray massive beds here strike N.65°W. and dip 20°SW. The strata dip about the same as the slope of the hill so that in one place the beds form a capping to the hill. On the brow of the hill just north of the road that runs east across the hill from East Allentown some specimens of the large size *Scolithus* were found.

Due to faulting the Hardyston is unrepresented on the south side of the Rittersville Hill except at one place southeast of the hospital where a small wedge of the sandstone has been faulted into the gneiss.

South Mountain between Fountain Hill and Allentown.—The first occurrence of the Hardyston sandstone is within the grounds of St. Luke's Hospital. A very good outcrop of arkosic sandstone occurs at the southwest extremity of the Hospital buildings. About ten feet of buff quartzite overlie about six feet of shaly, altered sericitic rock. On the steep slope just north of the exposure the rock appears to be a badly sheared gneiss underlying the slaty basal Hardyston. The Hardyston here strikes N.17°E. and dips 40°SE.

About 50 feet north of this outcrop there is another exposure of thick beds of sandstone which strike nearly N-S, and dip 40°E. About eight feet of quartzite is present, resting on the sheared zone. There is another outcrop of what appears to be sheared Hardyston 100 feet still farther north.

At the northeast nose of the mountain north of St. Luke's Hospital there is an abandoned quarry in the Hardyston. At the bottom of the quarry Byram gneiss is exposed. Above this there is about four feet of green and red slaty rock called pinite, which here is impure and composed chiefly of sericite and quartz. Above this there is exposed about ten feet of buff arkosic sandstone with a basal conglomerate. The sandstone strikes N.68°W. and dips 25°NE.

About one-fourth of a mile west there is another quarry, almost directly opposite the plant of the Bethlehem Fabricators on the north side of the Lehigh River. The rock is a buff arkosic sandstone with strike N.72°E. and dip 30°NE.

Proceeding westward the sandstone has been quarried at several places. A short distance west of the municipal pumping station the outcropping band gradually extends higher up the slope until it is almost at the crest of the hill where a quarry was worked for several years. A pronounced fault has broken and offset the band of Hardyston along the diagonal NW-SE road that crosses the mountain.

With the band again close and parallel to the river and railroad it continues uninterruptedly for about a mile. In this distance there is continuous quarryable sandstone and seven quarries have been worked, some of them small. The stone is easily worked and is very attractive for structural purposes. In some openings only about 10 to 15 feet of stone have been quarried. Pinite and conglomerate are exposed in the bottom of some of the openings.

The east-west band with all the beds dipping north does not bend around the end of the hill as in the case of the Rittersville Hill. There is a gap and then one comes to a band at the west end of the hill. The beds here dip west and considerable stone has been quarried.

It is a question whether the Hardyston is present on the south side of the hill north of Farmington. Talus and glacial material cover the surface. Occasional blocks of sandstone resembling that of the Hardyston have been noted. Both the writers have at one time or another mapped a band of Hardyston here, but the present view is that it is probably absent and an east-west fault brings the Tomstown in contact with the gneiss beneath the surficial cover of clay, sand, and boulders.

Gauff Hill to Leiberts Gap.—The longest continuous band of Hardyston is that extending from Gauff Hill to Leiberts Gap on the north slope of South Mountain. From Gauff Hill southwestward there is little evidence for the presence of Hardyston for about a mile, although occasional pieces of arkosic sandstone and conglomerate were found.

At the creek about a mile east of Mountainville, there is a marked and sudden abundance of Hardyston float. The rock here is presumably a basal conglomerate, consisting of pebbles up to 1½ inches in diameter embedded in an arkosic matrix. Just west of the creek there are two wells or test pits with Hardyston debris. From this location to the next creek, half a mile southwest, the gneiss-Hardyston contact continues. The contact is marked only by float, but at one point nine-tenths of a mile east of the crossroads at Mountainville there is a large block of gray sandstone partly exposed. This may not be an outcrop, but it definitely shows the presence of Hardyston.

About 200 yards southwest of this exposure of Hardyston, at the gully of the northward-flowing stream, there is a large outcrop of coarse pebbly conglomerate, with the characteristic pink pebbles in a dark green matrix. This outcrop does not afford any clear indication of the bedding plane. The contact is indefinite in the stream gully, due to gneiss float, but on the nose west of the stream the pebble arkosic phase of the Hardyston again appears.

Along the right of way of the Lehigh Valley Transit Company just south of Mountainville there seems to be a window of gneiss surrounded by Hardyston. In two railroad cuts the sequence shows that there is a definite occurrence of Hardyston higher on the hill than the first gneiss outcrop. At the highway to the west there is another occurrence of this window of gneiss. It apparently is not much longer than the distance between the road and the railroad, but because of the float the true extent is unknown.

The most northeasterly of the prominent line of limonite iron mines in the Hardyston is about half a mile east of Mountainville. The presence of Hardyston here is indicated by fragments of conglomerate and sandstone near the pit.

From Mountainville to Emmaus there is a continuous line of old iron mines, some worked by open cut and some by shafts. In this distance, presence of the Hardyston is proved by abundant arkosic sandstone and conglomerate fragments thrown out of the mines along with much jasper and siliceous iron ores that were discarded. In a few places the sandstone beds dipping away from the mountain form the footwall for the mine workings.

About one mile west of the Allentown-Philadelphia highway these mining operations are marked by an immense outcrop of jasperoid sandstone. (Plate 17.) Several huge blocks of this massive rock jut from the surface and form a low promonotory from which an excellent view of the great valley can be obtained. The character of this rock is very interesting. It is a coarse jasper ore or a fine-grained ferruginous sandstone. All traces of minor bedding planes are obliterated. Vein quartz is scattered sparsely through the rock. One of the most striking characteristics is the presence of tension cracks and even of solution cavities in the mass.

This jasper is about 20 to 30 feet above the gneiss, stratigraphically. In this intervening thickness of the Hardyston most of the iron mining on this part of South Mountain was done. For a distance of nearly two miles the outcrops of jaspery rock are practically continuous. The texture of the jasper varies, some of it being very fine grained. Everywhere the distance from the gneiss is about the same, and marked by the old iron mines.

The old pyrite mine in the Hardyston is located close to the gneiss contact about half a mile east of Wilbur. Some piles of pyrite ore are lying about, although the pyrite has oxidized considerably since the working of the shafts in 1918. The pyrite is in grains about 1 mm. in diameter. They are loosely bound together by a matrix of quartz.

South of the pyrite mine there are occasional exposures of arkosic sandstone with a strike N.20°E. and dip 40° to 55°NW.

All these exposures are near the gneiss-Hardyston contact. They definitely show a tendency for the basal part of the Hardyston to be conglomeratic. The pebbles are not larger than half an inch in diameter, but they are coarser than the grains of the sandstone which forms the basal member northeast of the pyrite mine. It is interesting to note that where the conglomerate constitutes the basal member the iron ore is usually some feet higher in the Hardyston. A replacement of conglomerate by limonite apparently is rare, although it is thought to have occurred in a few places.

The next outcrop of the Hardyston is in the sandstone quarry one-fourth of a mile east-southeast of Emmaus. The strike is N.33°E., dip 56°NW. Although the rock is a good-looking buff sandstone, the quarry is rather small and has not been worked recently.

From Emmaus to Leiberts Gap the Hardyston is mapped on the basis of fragments of arkosic sandstone, conglomerate, and jasper.

Leiberts Gap to Berks County Line.—There seems to be a break in the Hardyston along the north side of South Mountain in the vicinity of Leiberts Gap. If absent in the vicinity of the Gap, it again appears just to the west, passing a short distance south of Macungie and bending to the southwest before reaching Alburtis. Throughout the entire distance the Hardyston is mapped almost entirely on the basis of float rock. Jasper, arkosic sandstone, and conglomerate are all present. A few poor exposures of the arkosic sandstone in place have been found.

About 100 yards south of the Indian jasper pits south of Macungie there is an exposure of sheared arkosic sandstone. About 30 feet of strata is exposed. The beds dip toward the gneiss hill, this indicating overturning and probably faulting. Three measurements gave strike N.82°E, dip 40°SE, strike N.52°E, dip 15°SE, and strike N.45°E, dip 10°SE.

About the Indian jasper pits pieces of black, brown, yellow, red, and white siliceous rocks were found. Some of the black flint is brecciated and the cavities filled with brown jasper. Some of the yellow jasper has shrinkage cracks filled with nearly translucent chalcedony.

Lock Ridge.—The Hardyston sandstones are present on the north side of Lock Ridge and crop out at crest of ridge. Within the band as mapped, there is a line of pits where white clay was once dug. Pieces of sandstone and shale were thrown out, thus seeming to indicate that the clay occurred in a shaly layer overlying the sandstone.

Saucon Valley.—The Hardyston is poorly represented in the Saucon Valley. Normally it should crop out on the lower flank of South Mountain on the north side of the valley, but here it is commonly missing on account of an extensive normal fault. The dropping of a huge block has carried the Hardyston below the surface and at different places brought the Tomstown, Beekmantown, and Jacksonburg into contact with the gneiss. Careful search has been made for the Hardyston near the base of the mountain. There are no outcrops but there are some scattered pieces of sandstone and jasper. The accompanying geologic map shows only a short narrow band northeast of Vera Cruz Station. It is possible that this band extends farther both east and west but such evidence as is available is inconclusive.

From the Northampton County line a short distance south of Spring Valley and north of Franklin School a narrow band of Hardyston is present as determined in part by loose pieces of arkosic sandstone and yellow jasper. Slightly more than one mile west of Franklin School there is an old limonite iron mine shaft about 35 feet deep around which are pieces of sandstone and jasper. A short distance to the west there is an exposure of compact arkosic sandstone containing much fresh feldspar. The beds strike N.67°E., dip 52°NW.

Several outcrops of Hardyston around the west end of Saucon Hill are the site of a few small stone quarries. There is an excellent exposure in the railroad cut just east of the highway crossing. Some beds contain much pyrite.

The Hardyston is faulted out on the north side of Saucon Hill by a normal fault that apparently has brought the gneiss into contact with a block of Jacksonburg limestone. In the area between gneiss in place and the outcrop of Jacksonburg along the north bank of Saucon Creek there are no outcrops. It is possible that one of the other limestone formations may be present there, the outcrop being concealed by talus.

A narrow band of Hardyston is mapped extending westward from Center Valley for about 2½ miles. The evidence for its presence is conclusive for the east half of the band in that material either in place, or approximately so, can be seen in the cut of the Lehigh Valley Transit Company. The rock is a shattered jasper with many cavities lined with drusy quartz. There is little sandstone in the cut but in two small limonite mines to the west, one on each side of the electric line, considerable sandstone was thrown out with the jasper. Specimens were obtained that showed nicely the replacement of the quartzite by limonite.

The evidence for the continuation of the band westward to the north side of the hill on which Seiders School is located is not conclusive, as there are no outcrops and the pieces of sandstone and jasper in the soil are not abundant. A specimen found here by D. M. Fraser showed clearly under the microscope the replacement of quartz grains of the sandstone by jasper.

The narrow bands of Hardyston on the northwest and west sides of Applebutter Hill, the north side of Limeport Hill, and the north slope of Chestnut Hill are mapped on the basis of abundant pieces of jasper and sandstone in the hillside talus.

Vera Cruz-Shimerville.—Southwest of Vera Cruz there is a prominent occurrence of the Hardyston formation. Most of the rock is an arkosic sandstone, but true quartzite, jasper, and chert are also present in some quantity. As in several other localities, topography does not seem to have much bearing on the present location of the Hardyston, the saddle at Shimerville being 200 feet higher than the valley at Vera Cruz.

The most important feature of the Hardyston in this area is the persistence with which the formation occurs at the surface on the long sloping hill one mile southwest of Vera Cruz. It is true that the north slope of the hill represents a dip slope, but in no other locality in Lehigh County does the Hardyston occur, without a break, to the top of a gneiss ridge.

The southern contact crosses the railroad about 300 yards southeast of Vera Cruz. It is marked by much arkosic sandstone float. It follows the track southward, remaining about 100 yards east of the track. Just east of the north portal of the tunnel, the contact swings westward. At the entrance to the tunnel, there is a fine exposure of the Hardyston. The bedding planes are almost indistinguishable, but on the basis of pebbles and general lithology, the beds seem to strike NE-SW, with a dip almost vertical. This arkosic sandstone is the wall rock of the tunnel for about 100 feet. This is succeeded by about 6 feet of a greenish sheared rock, somewhat resembling the pinite phase of the Hardyston. It may, however, be a product of faulting. Directly beneath it the Pochuck gneiss is exposed, where the timbering of the tunnel begins. Much water issues from the vicinity of the contact. If a fault is the cause, it seems to be of small displacement, since the Hardyston to the west of the tunnel seems to be quite normal.

West of the tunnel the contact crosses the road junction and continues southwestward across the next gully. On the hill just east of the gully there are several outcrops of the Hardyston. Although no good bedding plane could be seen, cross-bedding and lines of pebbles help somewhat in determining a strike N.35°E. and a dip 40°NW. Much fracturing and subsequent filling with vein quartz and cryptocrystalline silica was noted.

The contact runs a little south of west up the nose of the hill to the very top. Some of the Hardyston in the fields on the east slope of this hill is a very compact blue quartzite, quite pure. It rings almost as clearly as diabase when struck with a hammer. Other pieces of the Hardyston on this hill are very coarse arkosic types, characterized by exceedingly fresh feldspar. A few pieces of jasper were found near the gully to the east.

Hardyston occurs along the top of the hill but not definitely in place, so that strike and dip could not be measured.

Southwest of Shimerville the southern contact follows a stream with gneiss on the other side. A peculiar type of Hardyston occurs along the north side of the stream. The rock is a breccia of the sandstone type of Hardyston cemented by limonitic material. Some of this limonitic filling was found to approach hematite when studied in thin section. The contact swings slightly north of the creek at the road at the foot of the hill. Here the typical phase is again the arkosic sandstone.

Hill north of Vera Cruz.—West of Vera Cruz schoolhouse and on the crest of the hill north of Vera Cruz are the old jasper workings of the Indians. The jasper about the pits is mainly yellow to brown. The rock has been greatly shattered and the irregular to angular cavities lined with small quartz crystals. Macroscopic and microscopic tension cracks, filled in with later generations of chalcedony and quartz, are here beautifully shown. No specimens of arkosic sandstone have been noted about these pits, but some pieces of rock show the transition from fine-grained quartzitic sandstone to jasper.

Sigmund.—The straight narrow valley extending from the Berks County line eastward through Sigmund shows no outcrops of Hardyston, but there is throughout the area shown on the map an abundance of Hardyston ferruginous siliceous and arkosic sandstones. There seems to be a continuous band of Hardyston and not detached small areas as shown by Stose and Jonas (1935). The north side of the valley is presumably a fault, as indicated by springs. The hamlet of Red Hill gets water from a large spring here. An iron mine in the eastern end of the Hardyston area, as mapped, seems to have been in this formation.

Old Zionsville.—Southeast and east of Old Zionsville is an important area of Hardyston. It is possible that this area should be connected with the preceding one. There are no outcrops, but in the fields there is an abundance of loose arkosic and siliceous sandstones, ferruginous chert, and conglomerates. Some doubtful specimens of *Scolithus* were found. Thus it appears that the view expressed by Stose and Jonas (1935, p. 772) that the Hardyston present represents the upper beds brought up by an anticline is not correct in that the basal bed represented by the conglomerates is also present. The iron mine a short distance northwest of the railroad in the eastern part of the area shows enormous masses of ferruginous chert, and arkosic and siliceous sandstone were noted near the openings.

Hosensack.—In the Hosensack region there has been so much faulting that it could scarcely be expected that any two geologists would exactly agree in the location of the faults and the other formation lines. Beginning at the Berks County line the Hardyston is represented by abundant loose blocks along the hillside and at one place extending to the very top of a partially detached ridge. Several different kinds of rock are present. It varies from a quartzite to a sandstone. Some is arkosic but most is siliceous. Some quartz grains show elongation in parallel directions. Certain layers of medium-coarse sandstone contain abundant specimens of *Scolithus linearis.*

In a sandpit south of Hosensack station, fine-grained metamorphosed Hardyston beds rest upon decomposed gneiss and pegmatite. The conglomerate phase is absent and disproves the assertion of Stose and Jonas (1935, pp. 760 and 2039) that "the stratigraphic section of the Hardyston quartzite * * * is constant throughout the area, as can be demonstrated in the field."

Sheared, slickensided Hardyston beds crop out along the highway about one-fourth of a mile east of the crossroads at Hosensack village. Just north of Hosensack on the hillside along the highway there is an exposure of greatly metamorphosed, decomposed quartzite with strike N.41°E. and dip 38°SE. A small amount of stone has been quarried.

TOMSTOWN FORMATION

By Benjamin L. Miller

Distribution.—The Tomstown formation rests on the Hardyston and normally should be exposed in the vicinity of the Hardyston outcrops. This normal situation exists in certain places but in other localities no Tomstown exposures can be found in close association with the Hardyston and vice versa. This is in part due to faulting but more generally to concealment of outcrops.

Good exposures of the Tomstown are not common because of the position of the outcropping near the base of the larger hills composed of pre-Cambrian gneiss. Hillside talus conceals the outcrops over extensive areas and to depths up to 50 feet or more. Residual soils and glacial and alluvial deposits also add to the surficial cover. For these reasons the formation lines as placed on the map are subject to revision as erosion or artificial excavations result in further exposures.

The Tomstown occurs in the south portion of the limestone valley which constitutes so large a part of Lehigh County. In Hanover Township it makes a continuous band on the north side of the Lehigh River from Bethlehem to Allentown. Outcrops are numerous along or close to the Central of New Jersey Railroad right of way. It is mapped north of the Rittersville Hill of gneiss and Hardyston sandstone, although not represented by outcropping beds. There are some excellent exposures in quarries on both sides of the Lehigh River in the southeast part of Allentown.

From Gauff Hill it extends to the southwest to the borders of the county in a band from less than half a mile in width to approximately

1½ miles. It underlies practically all of Emmaus, Macungie, and Alburtis. A prong from this band extends westward in the vicinity of the Lehigh Country Club with excellent outcrops along Jordan Creek near Western Salisbury Church.

The down-dropped block of limestone of the Saucon Valley contains considerable Tomstown. A series of faults breaks the continuity of the outcrops but the Tomstown continues the full length of the valley. A few isolated areas occur in the Hosensack Valley and near Sigmund.

A manuscript geologic map of portions of Lehigh County was exhibited by George W. Stose at a meeting of the section of Geography and Geology of the American Association for the Advancement of Science in Philadelphia December 28, 1940, in which certain areas represented on the author's map as Tomstown were mapped as Elbrook. Mr. Stose's map has not been made available for study so that it can not be discussed in detail. The brief view afforded during his presentation enabled the writer to note marked differences in the Stose and Miller maps. Most of these seem to concern areas where there are no outcrops. Mr. Stose has mapped certain areas as Elbrook in accordance with his structural interpretation of the gneiss hills of the region as parts of a great horizontal overthrust resting on Paleozoic limestones. The writer does not subscribe to this structural explanation and has mapped Tomstown strata in those areas contiguous to the outcropping Hardyston. Naturally the two maps are markedly dissimilar. It must be recognized that it is legitimate and necessary for one to map in accordance with his structural interpretation in the absence of exposures but such a map must not in turn be used as evidence. The writer has definitely refrained from using his mapping of areas without exposures as evidence supporting his view of the structure, a custom that sometimes has been employed.

Lithologic characteristics.—The Tomstown formation of the region is composed almost entirely of dolomitic limestones. Several types have been recognized. The most common is a thin-bedded, high magnesian, impure limestone with the individual beds less than one foot thick. This grades into a more argillaceous variety with an abundance of sericite, which produces a glistening silvery appearance on the bedding planes. In turn this passes into a true sericitic shale in which there are practically no carbonates. These shales have been noted in many places and may have a thickness up to ten feet although usually less than one foot. All these thin-bedded varieties break into thin fragments on weathering and are conspicuous in the surface soil or sub-soil.

Another phase of the Tomstown is a massively bedded dense dolomitic limestone in which individual beds are upwards of ten feet thick (pl. 22, A). Some of the finer-grained dense layers break with a distinct conchoidal fracture. On weathering it breaks into thinner layers than may be observable in the fresh rock.

The variations of the Tomstown are frequent and abrupt both within the individual beds and from bed to bed. Nowhere has any guide stratum been observed that can be definitely recognized in other exposures. If the structures of the region were not so complex, it is possible that this situation might not be the case.

Almost everywhere in the region the Tomstown has been shattered by earth movements and the old fissures filled with quartz veins. Locally the dolomitic limestones may contain large numbers of fine quartz veins criss-crossing in an intricate manner. Well-developed quartz crystals have been seen in some of the open fissures. The beds have also been impregnated with silica from the circulation of heated solutions. Black flint is abundant in the Tomstown in places (pl. 17, A). The flint may occur in nodules or irregular masses that cut across the beds or in lenses following the bedding planes. The irregular masses are seldom more than six inches in diameter but may be several feet. The lenses may extend for six to eight feet. These flints have resisted erosion and consequently have accumulated in the residual soils in great abundance in many places. All these flints appear to be replacements of the dolomitic limestones by ground waters. In places tiny angular quartz particles are distributed throughout the rock. Joint planes are abundant and in various directions so that it is difficult to obtain well-shaped blocks such as are desirable for building purposes. The bedding plane surfaces are generally rough or nodular.

Small, isolated, well-rounded grains of clear quartz are fairly common in the Tomstown limestones and are clearly seen on weathered surfaces. Rarely there are thin lenses of sandstone composed of similar grains in which the carbonates are almost entirely lacking.

In color the Tomstown limestone ranges from a dark steel-blue to a dirty yellowish-white color. On weathering the stone becomes light buff to chalky white. Some of the carbonaceous and more highly argillaceous beds are almost black when fresh but these too, on weathering, become lighter in color, usually a dirty white.

Oolites, edgewise conglomerates, ordinary limestone conglomerates, cross-bedding and ripple marks have been noted in various localities as local phenomena, and indicate the shallow water origin of the Tomstown. They are not distinctive features, as similar textures and structures occur in the other limestones of the county.

The distinguishing lithologic characteristics of the Tomstown are partly positive and partly negative. Small exposures or single specimens may not be sufficient to differentiate these strata definitely. Both the Allentown and Beekmantown may locally contain similar features to those just described. Where the exposures are more extensive, however, the thin beds of impure dolomitic limestones, the abundance of sericitic shales and the massive beds of dense dark blue dolomites are distinctive. Negatively the complete absence of *Cryptozoa,* so far as known at present, serves to separate the Tomstown from the Allentown. This criterion by itself should not be over-emphasized since it is recognized that elsewhere in the country strata both older and younger do contain these calcareous algæ.

Chemical composition.—The Tomstown limestones everywhere in the county are high in magnesia. No low-magnesian beds have been noted and very few with less than 18 percent $MgCO_3$. They are likewise almost universally high in their silica content, although some quarries worked for flux have yielded some stone with less than 2 percent SiO_2. The Tomstown magnesian limestones probably will average more than 8 percent SiO_2 and considerable search must be made to find quarryable stone low enough in silica to be desirable as furnace flux. This has been an unfortunate situation since several of the iron furnaces of the past were built in close proximity to Tomstown outcrops.

Thickness.—The complicated structures and the limited exposures thus far make it impossible to obtain any satisfactory measurements of thickness. At no place is the entire thickness exposed and in very few localities is there a contact exposed either with the underlying Hardyston or the overlying Allentown. Diligent search has been made for some locality where measurements might be made but without success. Variations in dip are so common that a practically complete exposure across the entire formation is necessary to determine the thickness, and such sections are not available. Estimates made from the best exposures indicate a thickness somewhat less than 1,000 feet.

Name and correlation.—Until the writer and his colleagues began their investigations in the region in 1907, no attempt had been made to subdivide the limestones between the Cambrian quartzitic sandstones (Hardyston) and the Ordovician cement limestone (Jacksonburg). These intermediate limestones were grouped under the name ''Kittatinny Limestone'' by the geologists of the New Jersey Geological Survey. Because the limestones of the New Jersey region are continuous with those of the Lehigh Valley it was only natural that the same term should be applied in this region. Although they are continuous throughout the Great Valley another term ''Lebanon Valley Limestones'' came into use for the same series between the Schuylkill and Susquehanna Rivers and ''Shenandoah Limestone'' for the Cumberland and Shenandoah Valleys.

When it became apparent that this group of limestones, in which both Cambrian and Ordovician strata are present, could be divided in somewhat the manner of those in the Chambersburg region, it seemed best to employ provisional local names, even though tentative correlations were suggested with the already named formations. In 1909 Wherry[1] proposed the name Leithsville for the lowest series of the Paleozoic limestones of the Lehigh Valley. The name is that of the small village in the south corner of Northampton County. This usage was followed in several publications. Later work, however, has seemed to indicate its correspondence with the Tomstown formation of the Chambersburg region and therefore that name is now substituted for the previously-used local term. The correlation is based on equivalent position with reference to underlying and overlying strata and on lithologic resemblances. The absence of fossils renders the correlation much less satisfactory than desired.

It has been suggested that the upper portion of the formation be differentiated and mapped as the Elbrook but it is the present opinion of the writer that with existing information this is not feasible, although it is probable that some of the upper beds of the Tomstown of this region represent the Elbrook of the southern portion of the State.

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[1] Wherry, E. T., Science, new series, vol. 30, p. 416, 1909.

The name Tomstown was proposed by Stose,[2] from Tomstown, Franklin County, Pa. Fossils found there indicate a Lower Cambrian age.

Stratigraphic relations.—The contact between the Hardyston and the Tomstown has not been seen anywhere in the region as it is so thoroughly concealed at the surface by hillside wash and surficial soil. The facts at hand seem to indicate that the two formations are conformable and that there is a series of shales transitional between them. The limonitic iron ores, once so extensively worked along the slopes of the gneiss hills, appear to have been largely developed in this transitional zone. Some of the earlier geologists regarded these shaly layers as part of the limestones but the writer considers them more appropriately referred to the upper portion of the Hardyston as described on an earlier page.

In few places have contacts of the Tomstown and the overlying Allentown limestones been observed. They appear to be perfectly conformable although the former is regarded as Lower and the latter as Upper Cambrian with no indication of a Middle Cambrian such as has been noted elsewhere in the Appalachian region.

LOCAL DETAILS

West Bethlehem.—One of the best exposures of the Tomstown in Lehigh County is along the Central of New Jersey Railroad in West Bethlehem. In the east part of the section the shaly phase is prominent. The remainder of the exposure is massive dolomite with thin beds or laminæ of sericitic shales. Some beds show fine banding. Black flint as limestone replacement is prominent. Some of the flint is in lenses with the long dimension parallel to the bedding planes whereas some occurs in irregular masses that cut the beds of dolomite (pl. 17, A). A few layers show some poorly defined stylolites. A short distance to the west near the railroad roundhouse there is a fine outcrop of rotten Tomstown shale.

East Allentown.—Several quarries and exposures in East Allentown show different kinds of stone. The stone has been quarried for flux, lime, and crushed stone. The rock is highly dolomitic but with occasional shaly layers. Shearing has taken place in some of the shaly or thin-bedded layers. Some of the massive beds are so extremely fine-grained and compact that they break with pronounced conchoidal surfaces. There are numerous beds of edgewise conglomerate composed of thin chips generally less than half an inch in length.

In the most easterly of the large quarries there is a layer of unusually coarse oolite in which the spherules are about the size of buck shot (pl. 16, C). The oolitic character is scarcely noticed except in the weathered rock where the spherules have either been entirely removed, leaving spherical cavities, or have been weathered to a light yellow porous condition in a matrix of dense, grayish blue stone.

Black flint is present in this locality but rare. The angular character of the flint and the sharp line of contact between the flint and the dolomitic limestone is striking. Small stylolites were noted in several places.

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[2] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.

In the quarries along the Central of New Jersey Railroad just north of the Hamilton Street bridge across the Lehigh River the Tomstown is well exposed. The upper portion of the hill is Allentown limestone. The exact separation between the two, based on lithologic differences, is not easily made. The presence of *Cryptozoon proliferum* in some of the upper strata furnishes the best evidence of the Allentown formation capping the hill.

At the east side of the most southerly large quarry, fissures in the shattered stone on hot summer days permit the egress of cold air that has entered subterranean caverns during the preceding winter.

Saucon Valley.—Although outcrops are rather infrequent in the Saucon Valley, and some formation lines drawn provisionally, there are several places where the Tomstown is well exposed. About a quarter of a mile southeast of Seiders School an outcrop in the road contains some limestone conglomerate. The conglomeratic character is scarcely noticeable except on weathered surfaces.

One of the places where the shaly phase is well shown is in a cut on the new highway about midway between Friedensville and Center Valley. The material is shaly to sandy. The porous character indicates that soluble carbonates have been dissolved from the original calcareous rock.

Two quarries have been opened in the Tomstown north of the east end of Applebutter Hill.

Jordan Creek.—Along and near Jordan Creek in the vicinity of Western Salisbury Church and the Lehigh Country Club the Tomstown is exposed in old quarries worked for stone for burning to lime. A fine recent exposure in a road cut near the crest of the hill about half a mile south of Western Salisbury Church shows the interbedding of shale and dolomitic limestones to advantage. One band of shale is about 5 feet thick.

A small quarry along the highway close to Jordan Creek south of the Lehigh Country Club exposes both shaly and sandy beds interbedded with thin beds of dolomitic limestone. One sandy layer about 15 inches in thickness shows fine ripple marks in several places.

Most of the stone quarried in the several openings in this section is massive dolomitic limestone. In one quarry a tunnel about 12 feet wide and 8 feet high was run into the hill to obtain stone from one 4-foot massive bed and 3½ feet of thinner limestones. The two desirable bands of good stone were separated by 1½ feet of sandy stone. Oolitic limestones are present in some of the exposures along Jordan Creek.

Lock Ridge.—The Tomstown presumably is present in a continuous band all along the northern slope of South Mountain but it is exposed in only a few places.

At one time an excavation in Emmaus exposed some shaly dolomitic limestones that were considered Tomstown. One of the best Tomstown exposures is in a small quarry about half a mile north of Lock Ridge and about the same distance from the Berks County line. Here dense, massive, bluish-white dolomitic limestone strata are interbedded with shaly layers. The dense dolomite beds have much vein quartz filling old fissures. There is also considerable black flint.

Sigmund.—Several limestone quarries are located a short distance west of Sigmund. Two are in Lehigh County and others in Berks County. They were worked for fluxing stone for the Sigmund Furnace and for stone for lime burning. More recently one has been worked for crushed stone. The rock is an unusually dense bluish-white, massive, and fairly homogeneous dolomite. In the quarrying operations a cave 65 feet long was encountered. An opening in the floor of the quarry served as a drainage channel.

Hosensack.—Limestone has been quarried on the south side of Hosensack Creek about three-fourths of a mile east of Hosensack village. Several kinds of stone are present. Thin-bedded, light-colored, highly magnesian beds are numerous. Also common are some brecciated and conglomeratic limestones. These beds probably were shattered when faulting occurred. Everyone who has investigated the area has noted the presence of faults with varying trends but so far as known no two persons have ever completely agreed as to the limits of the various small fault blocks.

At this point the Triassic overlaps the Tomstown limestones. The basal beds contain Triassic limestone conglomerates which may be readily confused with the Tomstown beds where the prevailing red color of the Triassic is lacking. Some loose pieces picked up here may be either Tomstown or Triassic.

ALLENTOWN FORMATION

Distribution.—The Allentown formation occupies a larger area than any of the other limestone formations of the county. It forms a continuous band from one to four miles wide that passes entirely across the county from east to west. It occurs also in isolated areas both north and south of the main band. It underlies part of West Bethlehem, practically all of Allentown, West Catasauqua, Fullerton, Wescosville, East Texas, and Weilersville.

Where the formation crops out along the Lehigh River and smaller streams, fine opportunities are offered for detailed study. It has been quarried in scores of localities and these quarries, now in large part abandoned, are also useful in geologic investigations. Residual soil and glacial deposits conceal the limestones on the uplands.

Lithologic characteristics.—The Allentown formation consists of dense bluish-gray to gray magnesian limestones in beds mainly from six to eighteen inches thick. Some shaly phases contain thinner beds whereas occasional layers are several feet thick. The thicker beds, however, break into thinner laminae on weathering.

One of the most characteristic features of the strata of this formation, and one which is fairly diagnostic, is the alternation of dark and light beds (pl. 18). In an operating quarry these distinctions of color are not readily observable whereas they are prominent in old quarries and in natural outcrops. They are mainly due to different amounts of carbonaceous matter but in part to varying amounts of magnesian carbonate. Those strata with high magnesian content which in fresh fractures may be grayish-blue, assume a lighter color on long exposure to the weathering agents and may even become chalky white and thus present a striking contrast to those beds with less magnesia which undergo less change in color. This criterion of alternating beds of different color for the separation of the Allentown from the Tomstown and Beekmantown unfortunately can not be used everywhere because it is not developed in every exposure. Also, some slight development of this same feature has occasionally been noted in the Tomstown formation.

Shaly bands occur in the Allentown formation but are much less common and thinner than those of the Tomstown. Bedding plane surfaces with silvery glistening overlapping flakes of sericite mica are noted in many exposures. These bear witness to the original argillaceous content of the strata and the subsequent metamorphic processes that developed the crystalline sericite.

Oolites are conspicuous as distinct layers or lenses and also as isolated grains. On fresh surfaces they are not plainly noticeable but can readily be observed on weathered rock. They vary greatly in size from microscopic grains to spherules resembling buckshot. In places they are white but elsewhere dark, almost black. Oolites are generally prominently developed in association with heads of *Cryptozoa,* either forming distinct layers or as isolated grains. Besides true oolites, one frequently finds weathered surfaces in which small roughly spherical to angular particles are abundant. Commonly they are darker than the dolomite matrix and smaller than the oolites.

A careful examination of the Allentown limestones will usually reveal some rounded grains of clear quartz. These suggest wind action since they are so much coarser than the particles composing the limestones. During heavy storms occasional grains of beach sand may have been blown from the nearby land. Layers of quartz grains up to six or eight inches in thickness occur in several localities. Almost invariably these sand layers are strongly cross-bedded. On fresh surfaces the rock is gray but becomes brown on weathering, by the oxidation of contained pyrite.

In several places as described in the detailed notes, there are well-developed limestone conglomerates.

Ripple marks, both large and small, are common in the Allentown limestones with mud (sun) cracks and edgewise conglomerate (intraformational breccia) likewise developed in places. The bedding plane surfaces generally are rough. The described phenomena indicate a shallow-water origin and explain the local variations in the strata even within short distances. The beds vary greatly both in thickness and in lithologic characteristics within a few hundred feet. Sections of exposures mean little for this reason and exact correlation of strata is impossible except where the exposures are in close proximity. No key bed or horizon marker has been found in the entire formation. Black flint such as occurs in the Tomstown is well developed in certain localities.

Mineralogical composition.—The microscopic examination of the Allentown reveals little other than calcite, dolomite, quartz, sericite and carbonaceous matter with occasional crystals of pyrite. In a microscopic study of the insoluble residues made by B. Frank Buie and described in an unpublished thesis, other minerals were noted. He examined carefully the insoluble residues of eleven specimens of Allentown limestone from the Chapman quarry of the Bethlehem Steel Co. east of Bethlehem. Quartz was almost the only mineral recognized in those grains that failed to pass through a 200-mesh screen, but in the finer material he identified feldspar, zircon, tourmaline, rutile, cyanite, corundum, garnet, topaz, pyrite, galena, and possibly fluorite. He regards the pyrite and galena as authigenic and the others as detrital.

Chemical composition.—The calcareous strata of the Allentown formation are almost invariably high in magnesia and are properly classified as dolomites. Perhaps, on an average, the $MgCO_3$ exceeds 35 percent although the range is from 5 to over 43 percent. Very seldom does even a single bed have less than 20 percent $MgCO_3$. This practically complete absence of low magnesia limestone at times is useful in distinguishing the Allentown and the Beekmantown formations as the latter contains much stone low in magnesia.

The silica content of the Allentown limestones has been investigated at different times because of their use for fluxing purposes by the operators of blast furnaces in the Lehigh Valley. Some analyses show even less than one percent SiO_2 but rock of this high character is uncommon. In quarries worked for flux some beds contain upwards of 10 percent SiO_2 which, of course, is undesirable. A fair average of utilized stone is probably 3 to 5 percent whereas in other places the average may be considerably higher. There is great variation within many of the large quarries.

Paleontologic characteristics.—Calcareous algae are abundant in the Allentown formation. They have contributed largely to the formation of certain beds and are found at different horizons. They were noted by Prime[1] in 1878 who described them as follows.

> The limestone sometimes possesses a very peculiar appearance, more closely resembling clam shells planted as closely together as possible with their convex sides uppermost. Although this structure has been carefully examined, no nucleus could be found accounting for such a formation.

They have been described as minor folds of inorganic origin. Emerson[2] described and figured a specimen of *Cryptozoa,* a dolomitic limestone from North Greenland and interpreted it as an inorganic structure. He says:

> The figure shows a curious banded concretionary structure in deeper shades resembling the landscape marble from Cotham, England. It is a distinct schlieren structure in a sedimentary rock, as if a heavier layer had settled upon a lighter, and the latter had at stated points risen up into the former. The lines of flow (are) marked by a delicate banding, and expanded outwardly into a fan structure.

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[1] Prime, F., Report DD, Pennsylvania Second Geol. Survey, pp. 14-15, 1878.

[2] Emerson, B. K., American Geologist, vol. 35, p. 98, 1905.

In recent years *Cryptozoa* have been accepted by geologists generally as organic structures. By some they have been regarded as animals, somewhat similar to corals or bryozoa but by most are considered as calcareous algae. Internal structures are not preserved so that their classification has been difficult.

On a bedding plane surface the *Cryptozoa* appear as small lumps from half an inch in diameter and about the same height to heads four feet in diameter and one to four inches in height. Some of the larger forms have a pimply surface of minor structures. In cross section they present a series of thin convex layers of dolomite that may aggregate more than a foot in thickness. In places certain layers weather much whiter than the matrix rock and at a distance a line of these heads appears as a series of folds or loops. The heads in association are generally of about the same size but not always.

Of the *Cryptozoa* observed in the Allentown dolomitic limestones of the Lehigh Valley there is a great variety (pls. 19 and 23). It is probable that a detailed paleobotanic study of these forms will result in the establishment of several different species but up to now no such investigation has been made and they are all classified as *Cryptozoon proliferum.*

In an article by C. L. and M. A. Fenton[3] calcareous algae from the Allentown limestone have been described as *Dolatophycus expansus* from Raubsville and *Anomalophycus compactus* from Portland, Northampton County. These forms have previously been called *Cryptozoa.* The Fentons had only a limited number of specimens for study. Other species generally described as *Cryptozoa* have been named in both New York and Maryland.

Cryptozoa have been used in the Lehigh Valley as criteria for the differentiation of the Allentown from the Tomstown below and the Beekmantown above. Some questionable forms have been observed in the Tomstown but in no case have any *Cryptozoa* been positively identified in that formation in this section. Undoubted *Cryptozoa* have been noted in the Martinsburg limestones northeast of Howertown, Northampton County, but in rock of entirely different character from that of the Allentown formation.

Animal remains are extremely rare in the Allentown but a few have been found and it is hoped that careful search will result in other discoveries from time to time. A few specimens of the brachiopod *Lingulepis acuminatu* have been found about 1½ miles southeast of Catasauqua. Weller[4] reports fragments of an Upper Cambrian trilobite, *Solenopleura jerseyensis* associated with an abundance of *Cryptozoa* in the southernmost quarry below Carpentersville, New Jersey, just across the Delaware River from Raubsville, Northampton County.

While B. Frank Buie, Fellow in the Lehigh University Institute of Research, was studying the insoluble residues of some specimens of Allentown limestone from the Chapman quarry of the Bethlehem Steel Co., located on the north side of the Lehigh River between Bethlehem and Freemansburg, Northampton County, during the scholastic year 1931-1932, he discovered some microscopic spherical siliceous forms of apparent organisms. Specimens were submitted to three of the outstanding specialists in the group of the foraminifera, all of whom agreed that the forms were organic but questioned whether they were foraminifera. Buie planned to continue his studies and eventually publish his discovery but his transfer to Harvard University interfered.

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[3] Fenton, C. L. and M. A., Cambrian calcareous algae from Pennsylvania: American Midland Naturalist, vol. 18, pp. 435-441, 1937.

[4] Weller, Stuart, Report on Paleontology: New Jersey Geol. Survey, vol. III, p. 13, 1903.

Later J. M. Hills[5] in his more extensive microscopic investigations found many specimens of these same organisms in the Allentown limestone, sufficient to determine definitely their zoologic classification. He says:

> These foraminifera are all of arenaceous types and are very simple in form. The majority have ovoid tests with simple apertures. Some, however, have tests which are nearly spherical, and many have necked apertures. A very few have as many as three or four chambers and a complex curved neck. The foraminifera occur most abundantly in the lower division of the Allentown . . . but some are found at lower horizons. These fossils present a most interesting opportunity for further study in the residues, as they are probably the oldest representatives of their order yet found in this country.

Thickness.—As with the other Paleozoic formations of Lehigh County, the thickness of the Allentown formation is undetermined. No exposure of the entire thickness is known in the region and the absence of any key bed or any group of beds that can be identified in different exposures, as well as the complicated structures, explain the lack. Thicknesses of 800 to 1,000 feet have been measured in several localities where the entire formation was not exposed. Along a ravine near Hope, Northampton County, 1,300 feet of Allentown beds was measured and neither upper nor lower contacts present. The best estimate that can be made at the present time is that the maximum total thickness is 1,500 to 1,600 feet and perhaps a few hundred feet more. As is usual in shallow water deposits the thickness varies greatly in a short distance although concealed faults may be the explanation for these marked changes.

Name and correlation.—The Allentown limestone has been so named because of its extensive and typical development in and about Allentown, Pennsylvania. The name was suggested by Wherry[6] in 1909. It seems to be the equivalent of the Conococheague formation in the Chambersburg[7] region, although there are some essential lithologic differences. Although the author has used the name Conococheague in other places, he is now inclined to return to the local name until careful geologic investigations have been made in the intervening area.

E. O. Ulrich regards the Allentown as the base of his Ozarkian period and the Pennsylvania Geological Survey places it at the base of the Canadian period. The U. S. Geological Survey regards it as Upper Cambrian, which meets with the approval of the author.

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[5] Hills, J. M., Jour. of Sedimentary Petrology, vol. 5, p. 130, 1935.

[6] Wherry, E. T., Science, new series, vol. 30, p. 416, 1909.

[7] Stose, G. W., U. S. Geol. Survey, Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.

Stratigraphic relations.—As stated above, the Allentown formation overlies the Tomstown and with apparent conformity, even though formations are missing which appear between these two in the south-central portion of the State. If there is an appreciable time gap here, it is hoped that evidence of the events of that time will eventually be obtained.

The Allentown strata pass beneath the Beekmantown and again there seems to be perfect conformity. This contact is nowhere well shown in Lehigh County. Along the Lehigh River there are several exposures near but not at the exact contact.

Although in general all the Paleozoic formations of the county appear as outcropping bands in order of decreasing age, there are several places where folds or faults have brought certain formations to the surface in other than the regular arrangement. The general dip of all the strata is to the northwest at varying angles but complex structures have resulted in varying dips and strikes. Overturning of folds in the Fullerton region has resulted in a preponderance of southeasterly dips.

LOCAL DETAILS

There are so many and such excellent natural and new exposures of the Allentown strata along the streams and railroads of the county and in quarries and road cuts that it is difficult to select certain ones for special mention. Seldom can all the characteristics described above be noted in a single locality and in a few places there may be no one of them present. In such cases there may be differences of opinion as to the formation mapping.

Hanover Township.—The best exposures of the Allentown formation in Hanover Township are along Monocacy Creek in West Bethlehem. The beds are well exposed in an old quarry between the Broad Street and Union Boulevard bridges. Several kinds of well-preserved *Cryptozoa* are present. Near the top of the quarry some *Cryptozoa* heads are 1 to 2 feet in diameter and near the floor some are 3 to 4 feet with the upper surface covered with pustule-like prominences (pl. 19-A).

The Allentown formation is exposured also on the east side of Lehigh River from Adam Island northward in East Allentown.

City of Allentown.—There are scores of exposures within the limits of the city of Allentown, particularly along the Jordan and Little Lehigh Creeks. With the exception of a small area of Tomstown near the sharp bend of the Lehigh River south of Jeter Island all the outcropping limestones in Allentown belong to the Allentown formation.

The best place to see these limestones is in the large Ziegenfuss quarry in the southwestern part of Allentown. This quarry has long been operated. At one time most of the stone was burned for lime but in recent years the product is crushed for concrete and highway use. The stone is hard and dense dolomite. There is great variation in the thickness of the beds but little distinctly shaly material. The rock has been considerably shattered in places by earth movements. Minor folds and faults are present and much calcite and quartz in veins. A rather extensive cavern was encountered at one time. The alternating light and dark bands are noticeable and some layers contain many specimens of *Cryptozoa.*

Cuts of both the Lehigh Valley Railroad and Central of New Jersey Railroad in northeast Allentown expose the Allentown limestone with unusually large heads of *Cryptozoa* (pl, 19-B). The cut along the former is about 25 feet deep. The alternation between light and dark beds is prominent in the cut (pl. 18). Some sandy beds show fine cross bedding.

In exposures about Allentown one can find illustrations of many different phenomena such as mud (sun) cracks, oolite, edgewise conglomerate, ripple marks, folds, faults, sericitic surfaces, interbedded light and dark beds, different types of *Cryptozoa,* sandstone lenses, etc.

Jordan Creek above Scherersville.—There are numerous fine exposures of the Allentown dolomitic limestones along Jordan Creek from Scherersville north and northwestward for about two miles. The stone has been quarried in several places.

An exposure in the bluff along the road a short distance west of the entrance to the plant of the Trojan Powder Company shows sandstone layers as well as any place in the Lehigh Valley. A sandstone bed between layers of the dolomitic limestone is 14 inches thick in one place. It contains thin layers of limestone and irregular fragments and thin chips of limestone both parallel to the bedding planes and at various angles (edgewise conglomerate). The sandstone is composed of fine, transparent, well-sorted and well-rounded grains of pure quartz. The rock is firmly cemented by calcareous matter. Cross bedding is evident in some places.

The character of the sand grains suggests wind action. It may be that such a layer represents a local episode of short duration, probably a severe storm with high winds that carried the quartz grains from some beach or sand dune and dropped them in a region where strong waves were breaking up the recently deposited limestone oozes into flattened fragments. Where the land lay that furnished the sand is conjectural. It must have been nearby since sand grains of this size are seldom transported far.

All the known sandstone occurrences in the Allentown formation of the county seem to be of this character and so local that they can not be used for purposes of correlation.

Similar sandstones with fragments of enclosed dolomite have been found in North Allentown and in the vicinity of Helfrichs Springs.

Lower Macungie Township.—Most of Lower Macungie Township is underlain by the dolomitic limestones of the Allentown formation. Numerous exposures occur in road cuts, quarries, and on the sides and floors of old limonite iron ore pits. In most places *Cryptozoa* are present in some layers. Especially large heads occur in a large quarry in the grounds of the Brookside Country Club. One measured about 4 feet in diameter and 1½ feet in thickness. A short distance to the north of the Club in a large quarry some *Cryptozoa* heads are 2 to 3 feet in diameter and 14 inches high. They are made up of distinct layers, which are shown in cross section to be composed of minor prominences or loops about half an inch in diameter.

Most of the exposures in the township show the characteristic light and dark banding. The dark beds are dark bluish gray and the light-colored ones are cream white to chalk white. Thin shaly beds are not uncommon.

Saucon Valley.—The Allentown formation is not well represented in that portion of the Saucon Valley embraced within Lehigh County. It is present in detached fault blocks.

The most interesting exposure is at Limeport where the stone long was quarried. Here the dolomitic limestones are unconformably overlain by an isolated patch of weathered Martinsburg shale. The limestones here are less characteristic of the Allentown formation than in some other sections, but the presence of *Cryptozoa* furnishes the basis for referring them to this formation. Considerable oolite is present. A small cave was discovered in the quarry operations.

A quarry with several openings, about one-quarter of a mile southwest of Lanark, once worked for stone for burning to lime, contains some shaly beds and also massive layers. There is considerable edgewise conglomerate in certain beds associated with *Cryptozoa* heads but not in others. An uncommon phase present in this quarry is a massive bed of limestone conglomerate with the limestone pebbles ranging in size up to three-fourths of an inch. Most of the fragments are sub-angular.

ORDOVICIAN SYSTEM

BEEKMANTOWN FORMATION

Distribution.—The Beekmantown strata constitute the surface rocks in an irregular band averaging about three miles wide extending continuously east and west across Lehigh County. Beekmantown limestones underlie in part or entirely the villages of Shoenersville, Catasauqua, Hokendauqua, Guthsville, Walbert, Crackersport, Haafsville, Trexlertown, Breinigsville, Newtown, and in the Saucon Valley the village of Friedensville. Faults and folds on both sides of South Mountain have deformed the strata so that the regularity of the band has been destroyed. Wedges or blocks of the Tomstown, Allentown, and Martinsburg formations project into the band of the Beekmantown. The normal bounding relations are, on the south the older and underlying Allentown strata, and on the north the younger and overlying Jacksonburg cement limestones.

Surficial soils and glacial deposits conceal the beds generally in the uplands, but there are abundant outcrops along the stream valleys. In numerous places the limestones, of which the formation is almost exclusively composed, have been quarried for road metal, for flux, and for lime. These quarries furnish opportunities for study.

Lithologic characteristics.—The Beekmantown formation in Lehigh County consists almost entirely of alternating calcareous strata of varying composition and physical properties. High magnesian limestones (dolomites) are predominant, especially in the lower part, but there are many interbedded strata containing a medium to low percentage of $MgCO_3$. The dolomitic beds are generally more massive, considerably harder and tougher and can be readily differentiated by the driller and by the quarrymen.

The dolomitic beds range in thickness up to eight to ten feet and scarcely show lamination or bedding planes except on weathered surfaces whereas those layers containing a moderate or small amount of $MgCO_3$ are mainly less than one foot thick and in places so thinly laminated as to suggest shale. Thin beds or lenses of true shale occur although much less common than in the Allentown and Tomstown formations.

In many exposures the more highly magnesian beds are marked by numerous gash veins of quartz and calcite. Such veins are rare in the adjoining strata with low magnesia content. During folding the more massive, brittle and stronger dolomitic limestones were broken and jointed while the thinner bedded low-magnesian strata developed flowage (pl. 17-B), and fewer open joints persisted. There are abundant illustrations of the slippage of one bed on another in these purer limestones.

The joints in the dolomitic layers have been filled with quartz, dolomite and calcite. Many weathered blocks of dolomite have a maze of intersecting quartz veins projecting prominently above the surface.

Another prominent feature of the Beckmantown dolomitic limestones of the region, by which they can be distinguished from the underlying strata of the Allentown and Tomstown, is a conglomerate structure shown on weathered surfaces but scarcely apparent in the freshly broken rock, which is dark steel blue and appears fairly homogeneous. Irregular brownish-gray sandy patches project above a surface of bluish-gray matrix, and suggest organisms of the general character of *Bryozoa,* although no evidence of their organic nature has been obtained. The portions of each type are about equal in amount and there is no parallelism of arrangement. The origin of this type of rock is not known. The irregular shape of the patches does not seem to be what one would expect if waves had broken up earlier thin-layered deposits and transported the fragments to a place where a different type of deposit was forming. If they are of organic origin one may assign them to the plant kingdom and interpret them as sea weeds *(Fucoids?)* or perhaps to the animal kingdom as *Bryozoa* or allied forms.

Elsewhere in the State the Beekmantown formation contains in many places a banded variety of dolomitic limestone made of parallel dark and light layers or lenses, generally about one-fourth to one-half inch in width. No good examples of this type have been observed in Lehigh County.

Coarse dolomitic conglomerates (pl. 21, B) occur in several places and also greatly brecciated layers, some of which are original structures and others secondary. The individual fragments range in size up to eight or ten inches. Thin bands of edgewise conglomerates and oolites are occasionally seen.

True shales, without calcareous matter, are uncommon in the Beekmantown and where present are thin and thus furnish another criterion for distinguishing this formation from the underlying rocks. Thin layers of argillaceous material, now altered to sericite mica, occur on many bedding plane surfaces.

Siliceous beds in which there is a large percentage of quartz grains are rare. Secondary black flint lenses and irregular masses of large and small dimensions, formed by the replacement of limestones and dolomites, are prominent in regions that have undergone considerable disturbance by close folding and faulting but elsewhere are seldom noted. As the limestones are removed by solution these remaining flint masses accumulate in the residual soils and may be abundant. The segregations of black flint in the Beekmantown dolomites are especially abundant in the Friedensville region and fine examples can be seen in the waste heaps about the zinc mines.

The most unusual phase of the Beekmantown in Lehigh County is the rock composed of secondary quartz crystals that was thrown out of the large iron mine slightly less than one mile east of Lanark. The rock is thinly laminated, porous, taffy-yellow, and composed of small ferruginous quartz crystals. In the more compact portions the crystal faces can not be readily seen, but in the porous laminæ every particle shows well-defined crystal faces. Many of the crystals grew with so little interference that they show perfect hexagonal doubly-terminated forms. The crystals are not oriented. Some are parallel to bedding, some perpendicular, and others at all angles.

When these specimens were first found the writer regarded them as an unusual phase of the Hardyston sandstone. The color is almost exactly the same as the yellow jasper of that formation that is so well developed in the vicinity of Center Valley and on the north side of South Mountain between Mountainville and Emmaus. Similar specimens found in the fields east of Vera Cruz Station led to the mapping shown on the 1925 map of the Allentown Quadrangle. The further study of this strange rock and the evident close association with decomposed shaly Beekmantown limestone seem to point to its origin as a replacement of dolomite. Unfortunately the material has been observed in place nowhere in this region.

The writer's view of origin is confirmed by the investigations of apparently almost identical material described by Charles R. L. Oder [1] from the Jonesboro (Upper Cambrian) formation of Virginia near Elkton and Wytheville, where much more information could be obtained than in the Saucon Valley occurrences. The major part of Mr. Oder's article is quoted.

> The material upon which this investigation was conducted consisted of seven specimens of ferruginous sandstone in which the quartz crystals were embedded in a matrix of brown to reddish brown iron hydroxide, collected from the two localities mentioned. This sandstone is present as bands, not over ten inches thick, at the base of the Jonesboro (Ozarkian) formation, along the upper contact of the Elbrook (Upper Cambrian) formation. It is also found at intervals throughout the Jonesboro bed, from top to bottom.
>
> The sandstone is fine-grained to compact, thinly laminated brownish-yellow to gray in color, depending upon the amount of dolomite with which it is mixed.
>
> The quartz crystals, ranging in length from 0.50 to 1.20 mm. and in diameter from 0.20 to 50. mm. occur in clusters and as isolated grains. In the clusters a few of the smaller crystals were found intergrown with the larger ones, but usually they are present as separate individuals. In the cases of intergrowth the crystal faces exhibit indentations which result from the separation of crystals in crushing.

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[1] Oder, Charles R. L., Occurrence of doubly terminated quartz crystals in sandstone in the Shenandoah Valley, Virginia: Jour. Min. Soc. America, vol. 14, pp. 382-384, 1929.

The crystals usually display simple forms, hexagonal prisms, terminated by the plus (r) and minus rhombohedrons (z), equally developed. The only distortions observed were those resulting from the intergrowths of crystals in clusters.

The color results from hydrous iron oxide, originally dissolved in the silica gel in a ferrous condition and later changed to the ferric state. It appears that the silica had been uniformly stained by the iron before crystallization of the former.

Some of the specimens show pure white crystalline calcite, associated with the quartz and iron oxide. No perfect crystals of this mineral were found but good rhombohedral faces and a distinct rhombohedral cleavage were observed. Since the calcite has not been colored by the iron it seems to be of a later crystallization than the quartz.

These quartz crystals were evidently formed following the solution of dolomite by ground water, and the precipitation of quartz in its place.

The silica which formed the crystals was leached from the siliceous portions of the Jonesboro formation, 600 feet of which is composed of a very siliceous dolomite, heavily laden with chert.

The abundance, perfect development, and uniformity in shape and size of the crystals points to a full, free space for crystallization indicating not so much replacement as the occupation of space already made.

The solutions from which the silica crystallized must have encountered divalent calcium in the dolomite which induced the coagulation and precipitation of the silica.

The color of the quartz crystals came from iron hydroxide, leached from adjoining rocks, which had stained the silica gel previous to its precipitation.

Lithologically it is generally possible to separate the Beekmantown from the Allentown and the Tomstown strata by the characteristics described. However, some of these features are not confined to the Beekmantown and again, no one of them may be exhibited in local restricted exposures; also the low-magnesian limestones of the upper Beekmantown may be confused with the basal limestones of the Jacksonburg. Therefore, there is room for difference of opinion in certain localities and it is to be expected that other maps will be prepared from time to time in which the stratigraphic lines will not agree exactly with those shown on the accompanying maps.

Chemical composition.—The strata of the Beekmantown formation show wide variation in chemical composition, particularly with reference to the $MgCO_3$ content. To the writer's knowledge, cement companies looking for accessible high-grade stone to "sweeten" the low-lime cement rock have discovered numerous outcropping beds of Beekmantown limestones containing from 90 to 95 percent $CaCO_3$ and only 1 to 3 percent $MgCO_3$. In several cases they have occurred considerable expense in drilling certain properties, only to find that this type of stone was interbedded with dolomitic limestones containing over 40 percent $MgCO_3$ and that it would not be possible to operate a quarry by steam-shovel for material usable in the manufacture of portland cement. It was feasible for cement companies to operate such quarries only during the days when hand-loading prevailed and the low-magnesian stone could be shipped to cement plants and the high-magnesia could be sold to iron furnaces for flux or used for ballast or concrete.

No locality in Lehigh County has been investigated where, under present economic conditions, a large amount of low-magnesian stone of this formation might be quarried without being mixed with an excessive amount of dolomitic stone. In Berks County, the writer found a quarryable thickness of high-grade limestone within the Beekmantown, and it is not improbable that this county may locally contain similar material. Analyses are given in the chapter on Economic Geology.

Paleontologic characteristics.—Fossils are rare in the Beekmantown strata of Lehigh County, although it is probable that careful systematic search would yield successful results. Fragments of fossils are not uncommon. The most likely places to find them are on the weathered surfaces of the low-magnesian beds. About 1909 a Columbia University student found a gastropod in a loose block of limestone near the Ueberroth mine, Friedensville, which was recognized by A. W. Grabau as a Beekmantown form. Later one of the writer's students found a specimen of *Lecanospira* sp. in a small quarry south of the Friedensville church. In the same vicinity a specimen of *Ophileta levata* was found in a diamond drill core.

A few additional forms have been obtained from Northampton County in the eastward continuation of the Beekmantown strata north of South Mountain. They are *Liospira, Orospira* cf. *bigranosa* Ulrich, *Hormotoma* cf. *H. artemisia* (Billings), *Lophospira gregaria, Leiostegium,* and *Orthoceras.*

Thickness.—As in the case of the other Paleozoic formations of the region, there is no known place in the county where reliable measurements can be made. Continuous exposures across the entire formation are lacking; minor and major folds and faults are present and dips change so rapidly that one is not justified in assuming the continuance of any dip beneath concealed areas. Attempts to determine the thickness at several points, all of which necessitate several unproved assumptions, have given figures from 700 to 2,000 feet. It is probable that the thickness is approximately 1,000 to 1,200 feet.

Name and correlation.—In the publication of the First Geological Survey of Pennsylvania, these limestones formed a part of the II Auroral Limestone. They constitute a part of the II Calciferous Limestone of the Second Geological Survey, a part of the Shenandoah Limestone of the U. S. Geological Survey from 1892 to 1908. This series was designated the Kittatinny by the New Jersey Geological Survey. Wherry and Miller in publications beginning in 1909 adopted the local name of Coplay from the town of Coplay in this county. Later, however, the local name was dropped as the fossils indicate proper correlation with the Beekmantown formation of the Mercersburg-Chambersburg area. This conclusion has been confirmed by E. O. Ulrich.

If and when further paleontologic studies are made of the fauna of the formation, it will be possible to discuss more exact correlations.

Stratigraphic relations.—In the region there are few exposures of contacts of formations. Close association of the Beekmantown and the underlying Allentown seems to indicate conformable strata. There may be a hiatus between the two formations since the New York section contains beds apparently not represented in this region.

The upper surface of the Beekmantown is definitely unconformable with the overlying Jacksonburg in New Jersey as described by R. L. Miller.[1] He also presents evidence to support belief in a probable unconformity in Lehigh County, but with less positive information.

LOCAL DETAILS

It is not advisable to publish all the notes available on the various outcrops of the Beekmantown formation. Only those of the greatest importance are given.

Hanover Township.—The northern half of Hanover Township is almost entirely underlain by the Beekmantown. It has been quarried in several places, most extensively in East Catasauqua a short distance to the north of the Catasauqua-Shoenersville road. A line of quarries was opened along the strike of the beds. Layers that were both high and low in $MgCO_3$ were worked. Near the west end and separated from the main face is a beautiful example of a small anticline overturned toward the north (pl. 23). The thickening of a dolomite bed at the crest of the anticline and the adjustment by flowage of the low-magnesian layers is striking.

The small hill in the extreme northeast corner of the township is composed of Beekmantown. The beds are almost all highly magnesian. Several quarries have been opened in the hill, some of which are in Northampton County.

Several other quarries along the Lehigh and New England R. R. east of Catasauqua and in other parts of the township show similar features.

Lehigh River, west side.—There are numerous excellent exposures of Beekmantown on both sides of the Lehigh River from Coplay to Fullerton, principally along the railroads, and on the west side of the river from Coplay to the borders of Allentown. Small areas of both the Jacksonburg and Allentown formations introduced by folding and faulting break the continuity of the Beekmantown exposures.

The contact between the Jacksonburg and the Beekmantown is in a quarry along the railroad just south of Coplay Creek. The Beekmantown is mainly dolomitic, but with some thin shaly beds. In another quarry a short distance to the south the strata are beautifully folded. The best of the folds are now concealed by garbage and other rubbish.

Along the railroad in Hokendauqua, a short distance north of the old iron furnaces, the Beekmantown shows some of its most characteristic features. Different beds are mottled and pitted on the weathered surfaces. The limestones are massive and fairly low in magnesia. Some layers are shaly.

Immediately north of the Ironton R. R. and close to the Lehigh Valley R. R. there are two quarries. The more northerly one is definitely in the Beekmantown formation and the one around the nose of the hill to the southwest shows Jacksonburg limestone. Certain beds have numerous tiny crinoid stem plates on weathered surfaces.

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[1] Miller, R. L., Stratigraphy of the Jacksonburg Limestone: Geol. Soc. America Bull., vol. 48, pp. 1687-1718, 1937.

Along the Lehigh Valley R. R. just below the Catasauqua station and Pine Street bridge there is a section exposing Beekmantown dolomite that weathers to a buff color interbedded with thin, low-magnesian layers that appear sandy on weathered surfaces. The strata have been folded. In the process the dolomite beds were thickened on the folds, and the low-magnesian limestones flowed about the dolomite irregularities. The brittle dolomite was broken during the folding process and the cracks were later filled with calcite and quartz veins, whereas the low-magnesian beds form a striking contrast with very few veins.

About half way between the Pine Street and the lower Catasauqua bridges there is an outcrop of Allentown beds showing the typical light and dark bands and some *Cryptozoa.* The Beekmantown appears again just above the lower bridge.

Two quarries near the Fullerton station show interbedded bluish, thinly banded, low-magnesian limestones and buff to gray dolomite. Another band of the Allentown formation underlies part of Fullerton.

Along the Lehigh Valley R. R. in the south part of Fullerton there is a fine exposure of overturned strata. The beds strike N.68°E., dip 41°SE. The north end of the section is Beekmantown dipping beneath Allentown at the south end. The overturning is shown by the upside-down heads of *Cryptozoa* (pl. 23). Besides the *Cryptozoa* the Allentown beds show the alternating light and dark beds, and the Beekmantown formation is identified by the interbedded high- and low-magnesian strata. There seems to be perfect conformity throughout and there is some question where the exact boundary line should be drawn. At track level the line is drawn about 30 feet to the north of a small spring.

Lehigh River, east side.—Just south of Catasauqua and a short distance east of the mouth of Hokendauqua Creek there is a large quarry in the Beekmantown. The dense, massive dolomite beds contain abundant calcite and quartz veins whereas the thinly banded low-magnesian strata contain few veins. The beds are complexly folded. On the east wall there is a fine illustration of broken dolomite with low-magnesian beds wrapping about the chunks of dolomite. During the folding the stronger dolomite layers yielded by fracture and the weaker low-magnesian beds by flowage (pl. 17-B).

A short distance to the south along the towpath of the canal the interbedded low- and high-magnesian beds crop out. The latter are much jointed.

In a Beekmantown quarry opposite Fullerton the low-magnesian beds show fine folding and crumpling, and the dolomite layers are only slightly deformed.

Whitehall Township.—In the vicinity of Egypt there are several outcrops of the dolomitic Beekmantown between the Jacksonburg and the Martinsburg. Overturning or thrust faulting cause the Jacksonburg in several places to dip beneath the Beekmantown.

The Beekmantown also underlies Coplay, West Coplay, and Hokendauqua.

The contact between the Allentown and Beekmantown is just north of Helfrichs Spring. On the east side of Jordan Creek, opposite the spring, there is a good exposure of the Beekmantown, and on the opposite side of the hill, west of the spring, a quarry has been opened in which most of the stone is low in magnesia but with some interbedded layers of dolomite.

North Whitehall Township.—All of the iron mines in North Whitehall Township are in the Beekmantown limestone. Limestone crops out in the sides of some of the mines at Ironton. Generally the dolomitic phase is more prominent than the interbedded layers low in magnesia. The best exposures are in the large quarry of the Lehigh Stone Company in South Ormrod. Owing to overturning here, the Jacksonburg dips under the Beekmantown.

South Whitehall Township.—There are many large quarries in the Beekmantown limestone along or not far from Jordan Creek from Greenawald to Guthsville. Limestone is exposed also in the sides of several of the old iron mines and in the bottoms of some of the abandoned workings. Practically every opening shows both high- and low-magnesian beds but with the low-magnesian type generally more abundant. From one of the quarries a short distance northeast of Guth Station, some of the low-magnesian stone is reported to have been separated from the interbedded dolomite and shipped to one of the cement companies. A property on the south side of Jordan Creek also is said to have been prospected by drilling by another cement company, but no attempt was made to open a quarry because of the amount of interbedded dolomite.

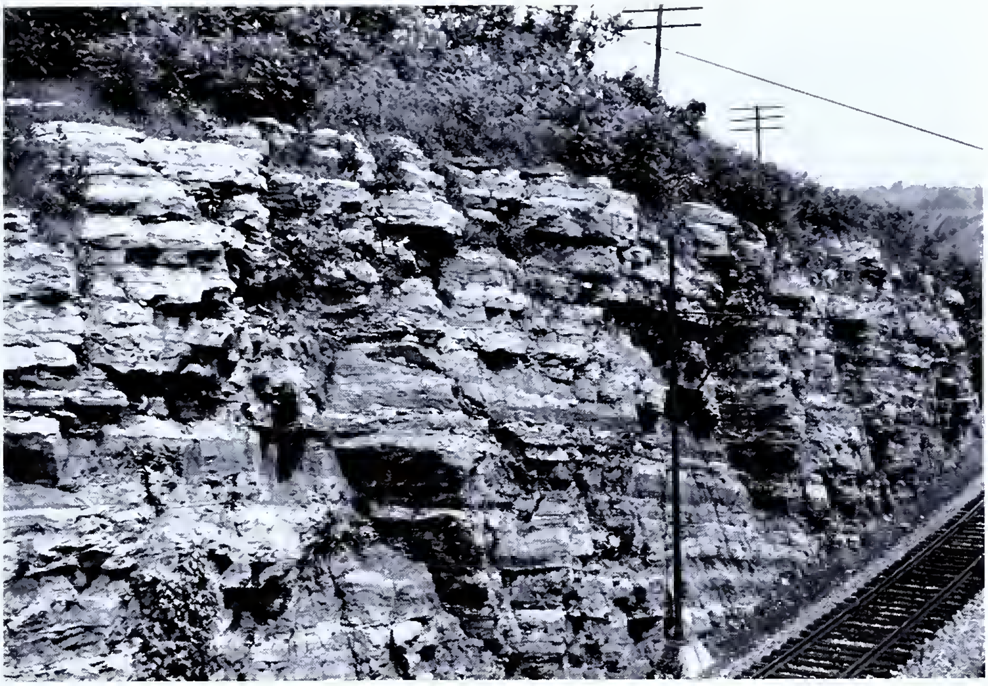
Some small quarries and outcrops north and northeast of Schantz Spring show well the characteristics of the Beekmantown.

Upper Macungie Township.—The Beekmantown limestones are the surface rocks in more than half of Upper Macungie Township. They are exposed in many outcrops, quarries, and along the sides of old iron ore pits. In almost every place the interbedding of the soft, bluish, thin-bedded, low-magnesian limestones and the massive dolomitic layers can be observed. Where quarrying for lime burning was done there seems to have been an attempt to take the low-magnesian rock, although both types were used.

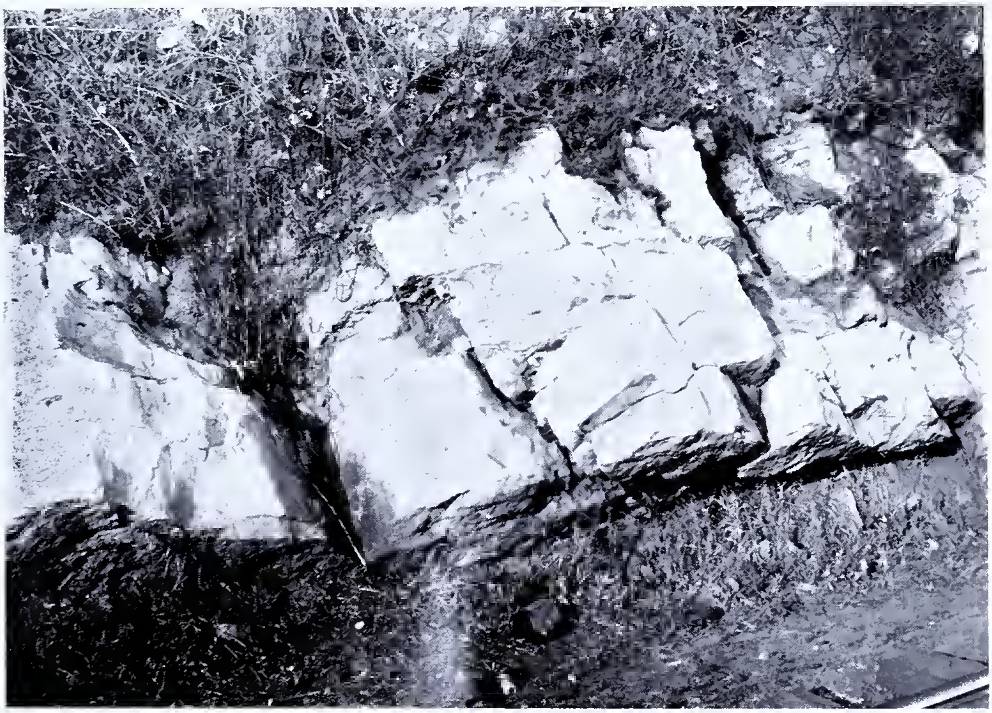
About 1½ miles northwest of Trexlertown in a quarry once worked for stone to be burned, the Jacksonburg in the southwest part of the opening apparently rests conformably on the Beekmantown. However, the Jacksonburg is near the surface and so much weathered that the true relationship may not be revealed.

A large opening slightly more than half a mile north of Trexlertown is said to have been an iron mine, although no ore is seen about the pit, and limestone is exposed on the north, east, and south sides. The rock on the north side is quite certainly Jacksonburg, as it is black, thin-bedded, and has many plates of crinoid stems on weathered surfaces. The stone on the south side is doubtfully referred to the Beekmantown. If it is, then the contact is within the opening.

In the Fogelsville quarry of the Lehigh Portland Cement Company some Beekmantown limestone, by overturning, rests on top of the

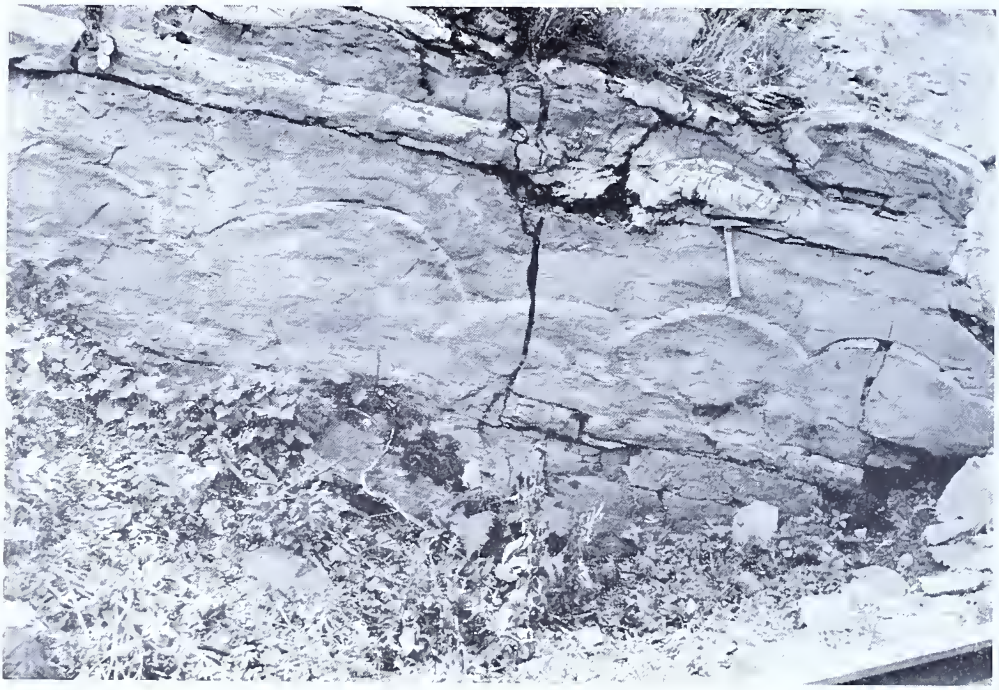


A. Typical dolomitic limestones of the Allentown formation showing alternating light and dark beds. Along Lehigh Valley Railroad northeast Allentown.

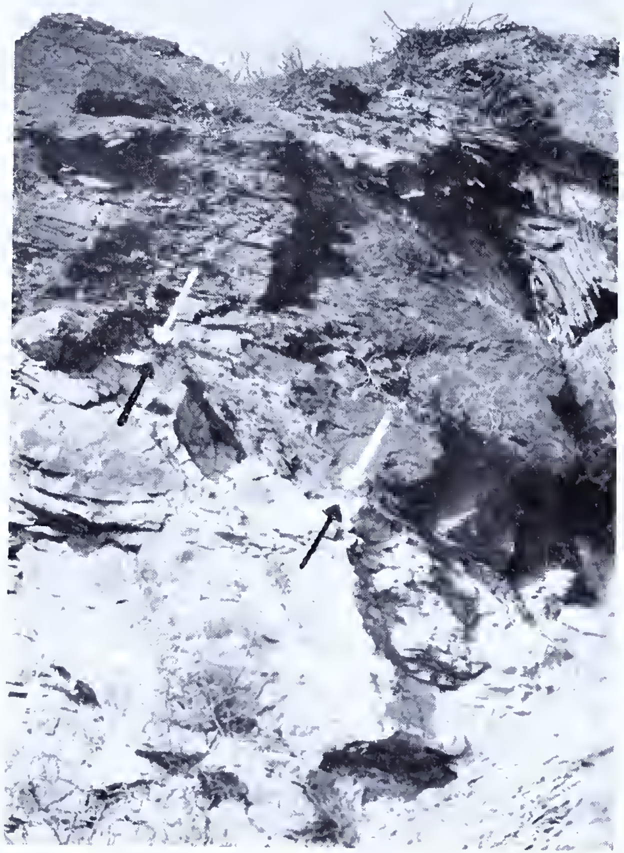


B. Close view of alternating light and dark beds of the Allentown formation. West Bethlehem.

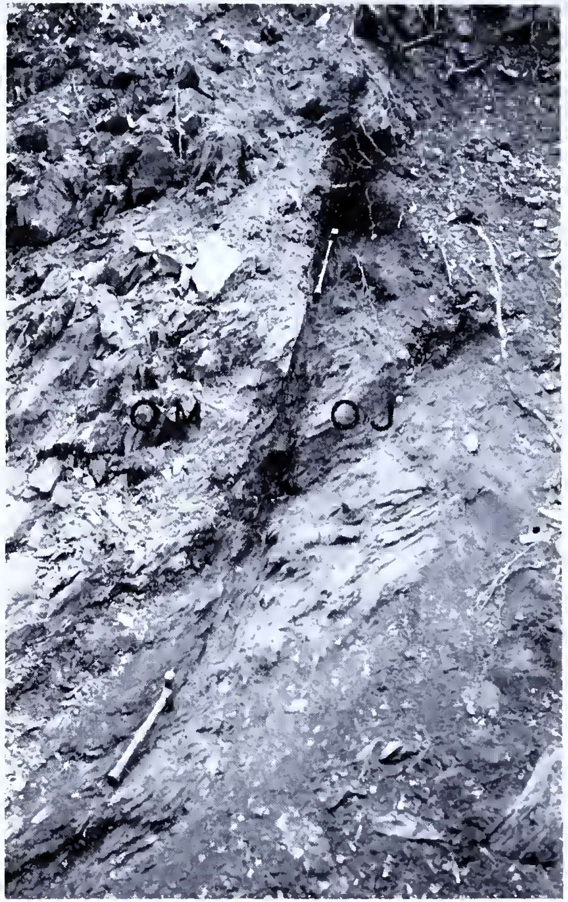
A. Tops of large heads of *Cryptozoa* in Allentown formation. West side of Monocacy Creek, Bethlehem, north of Broad Street bridge.



B. Cross-section of large heads of *Cryptozoa* in the Allentown formation. Along Central Railroad of New Jersey, northeast Allentown.

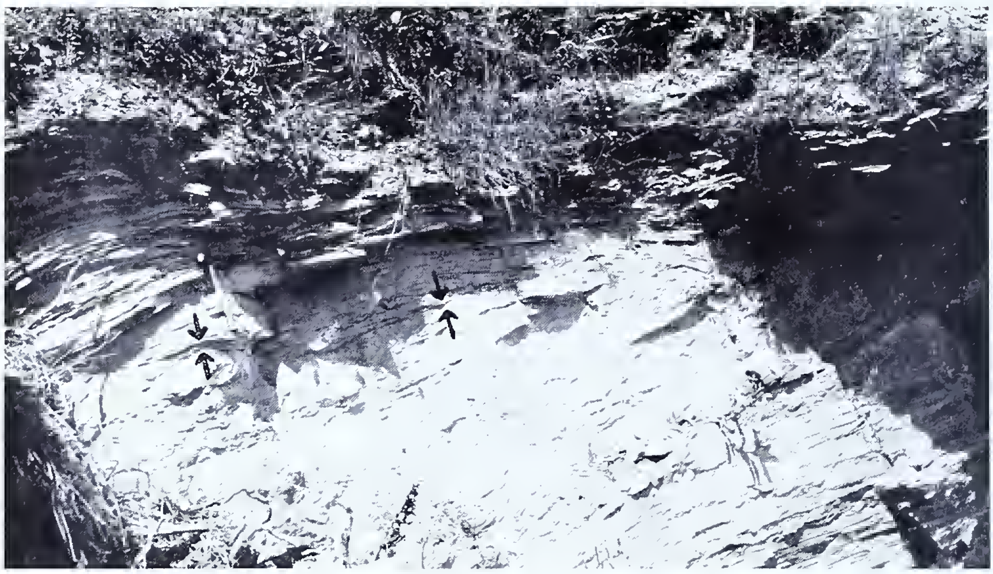


A. Martinsburg shales unconformably overlying Allentown dolomitic limestones in Limeport quarry.



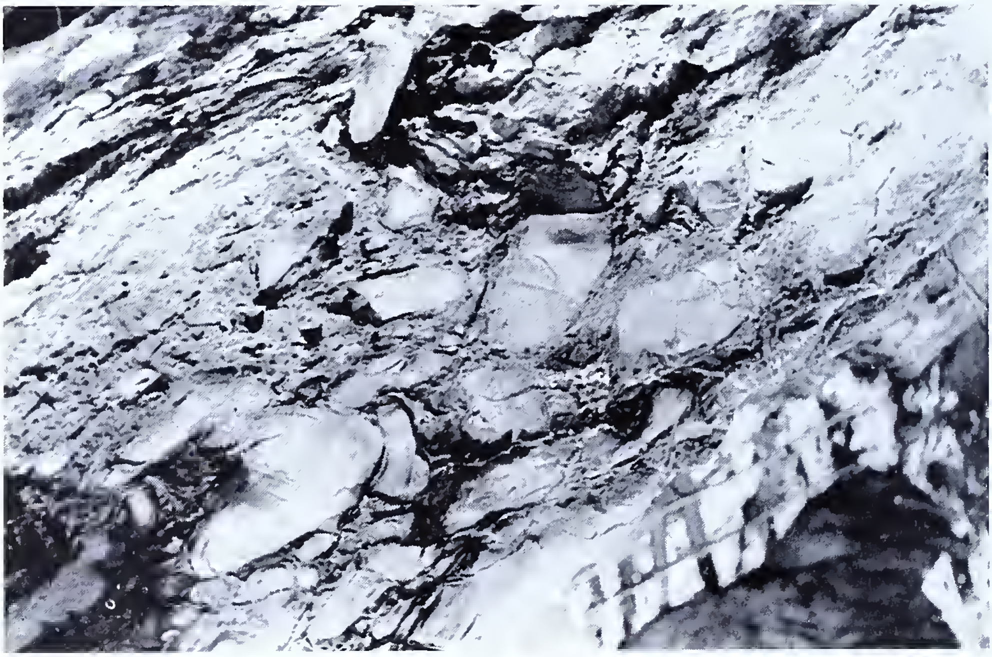
B. Contact of Martinsburg shales and Jacksonburg limestone 1 mile north of Fogelsville.

Martinsburg shale (OM) lies to the left, Jacksonburg argillaceous limestone (OJ) to the right. Both hammer points are exactly in the contact crack, and the hammer handles point in the direction of the contact.



A. Contact of Beekmantown and Jacksonburg in quarry near Trexlertown.

Arrows indicate location of contact. Hammer handle spans transition zone, and hammer head is at lowest bed of typical Jacksonburg lithology.



B. Coarse limestone conglomerate (or breccia) in the Beekmantown formation, Friedensville.

Jacksonburg. Also an area of Beekmantown lies south of the plant and a short distance north of the main highway.

Directly north of Newtown, about half way up the slate hill, there is a small quarry of Beekmantown limestone in which the beds strike N.33°W. and dip 6°NE. into the hill. Most of the stone appears to contain a medium amount of magnesia, but interbedded with some soft bluish-white, low-magnesian strata. The contact with the Martinsburg is not seen, but apparently it is only a short distance farther up the hill. Quite certainly there is no Jacksonburg present.

Upper Saucon Township.—Three areas of Beekmantown limestone are present in Upper Saucon Valley. The most prominent of these is the one that contains the Friedensville zinc mines and extends west almost to Lanark. The great rock piles about the mine openings afford an excellent opportunity to see the character of the fresh stone. Almost all the stone is highly magnesian, so that lithologically it is not the typical Beekmantown. The discovery of Beekmantown fossils here, as described on an earlier page, was therefore especially welcome. The strata have been much disturbed and black flint is more abundant than in any other Beekmantown area in the county. The waste rock near the Correll mine yields fine specimens.

The conglomeratic phase of the Beekmantown is beautifully exhibited at the Old Hartman mine. Some single pieces of dolomite within the dolomitic matrix are as much as a foot in diameter (pl. 21-B). Most of the fragments are angular so that the bed may almost as well be termed a breccia. Doubt expressed has been as to whether the conglomerate is original or is a fault breccia. The writer inclines to the view that it is original and was produced by storm waves in the Ordovician sea breaking up portions of the partially consolidated dolomitic ooze. There seems to have been only slight transportation, if any, from the place where the material originated.

Another more unusual type of rock in the Beekmantown of the Saucon Valley is the ferruginous sandstone, described on a previous page, in which the individual grains are quartz crystals. This was found in the old iron mine about a mile east of Lanark and picked up in the fields.

The bluish-gray, low-magnesian Beekmantown limestone is present in the abandoned quarry about three-fourths of a mile east of Lanark.

Several quarries in the detached area of Beekmantown limestone a short distance west of Lanark exhibit an interbedding of low- and medium-magnesian beds with few or no highly dolomitic layers. In this respect the limestone presents a sharp contrast to that at Friedensville.

A small area of Beekmantown is located a short distance southwest of Center Valley. Three quarries here show several types of stone. The strata in the most easterly one are mainly dolomitic and are much shattered and faulted. In the other quarries both low- and high-magnesian beds are present.

JACKSONBURG FORMATION

By Ralph L. Miller

Distribution.—A series of impure black limestones overlies the Beekmantown formation in parts of Lehigh County and is in fault contact with older formations at other localities within the county. These limestones are of restricted areal extent and thickness, but they form the most important economic formation within the county because of their utilization for the manufacture of portland cement. The name Jacksonburg limestone is here applied to this series, for they are correlated with limestones of similar lithologic and paleontologic characteristics for which the name Jacksonburg has been used in Northampton County[1] and in northern New Jersey.[2] The type section of the Jacksonburg limestone is located at the village of that name near Blairstown, Warren County, in northwestern New Jersey.

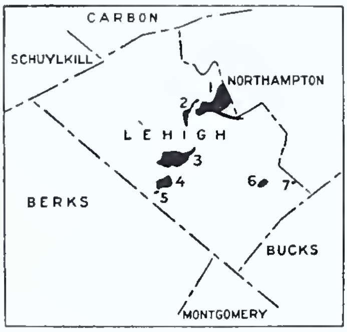


Figure 9. Map showing distribution of the Jacksonburg limestones in Lehigh County. Areas are numbered in the order they are discussed.

The Jacksonburg formation forms the bedrock in approximately 10½ square miles or 3 percent of Lehigh County. It is present as a series of more or less elongate areas (fig. 9) at or near the base of the Martinsburg shale hills, and as two small down-faulted patches in Saucon Valley in the southern part of the county. The discontinuity of the Jacksonburg formation in Lehigh County is in striking contrast with its distribution in adjoining Northampton County, where it forms a continuous belt of rather uniform width from the Lehigh County border northeastward for 26 miles. The reason for the patchy distribution will be discussed later.

The largest and most important area of Jacksonburg lies near the eastern edge of Lehigh County (fig. 9, 1). It forms the western end of the cement belt of eastern Pennsylvania. In Lehigh County this area includes the boroughs of Cementon and West Coplay, and the cement plants of the Whitehall Cement Manufacturing Co., the Coplay Cement Manufacturing Co., the Giant Portland Cement Co., and the Ormrod plant of the Lehigh Portland Cement Co. Many large quarries, both active and abandoned, which have supplied the cement mills since 1879, lie within this area. The extreme eastern part of this belt of Jacksonburg occupies its normal position at the base of the Martinsburg shale hills, but most of the area is bounded by faults and thus is out of its normal position. A narrow projection of this area extends southeastward across the Lehigh River to the borough of Catasauqua, faulted on the south but in normal contact with Beekmantown limestones on the north.

A belt of Jacksonburg three miles long and one-quarter to half a mile wide (fig. 9, 2) lies a short distance west of the area described above. It occupies a normal position between the Beekmantown limestones to the southeast and the Martinsburg shales to the northwest. There are no quarries of any importance in this area, and the belt is known and mapped mainly on the basis of small exposures in roadcuts and ditches. The northwest border of this area is known with a high degree of accuracy; the southeast border is believed to be located accurately, but the two ends of the belt are imperfectly known. The belt may stretch farther than shown on the map, especially in the southwest direction.

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[1] Miller, B. L., Fraser, D. M., and Miller, R. L., Northampton County, Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. C 48, 1939.

[2] Spencer, A. C., and others, U. S. Geol. Survey Geol. Atlas, Franklin Furnace folio (no. 161), 1908.

A sizeable area of Jacksonburg is almost centrally located in Lehigh County (fig. 9, 3), including Fogelsville, Chapman, and Kuhnsville. The rock of this area is well exposed in the large quarry of the Lehigh Portland Cement Company (Fogelsville plant). The limits of this area are believed to be accurately known on the north and west sides, are somewhat less well known on the south side. They are, however, imperfectly known along the southeast border with the Beekmantown formation and at the southeast tip of the area where there are few exposures because of a heavy mantle of Illinoian morainal drift.

The Jacksonburg formation crops out south of the area just described and west of Trexlertown (fig. 9, 4). This area is quite extensive, but the bedrock is poorly exposed. Most of the outcrops consist of a few inconspicuous beds in shallow roadcuts or ditches. The limits of the area are well known along the east and southeast margins. It is poorly known on the west side, however, where the Jacksonburg appears to be separated from the Martinsburg shale belt by a narrow strip of older Beekmantown limestones. A small patch of Jacksonburg (fig. 9, 5) ringing around a small Martinsburg shale knob is believed to be isolated from the larger Jacksonburg area just described. It is known only from two outcrops, but it may have a greater extent along the base of the shale hills than indicated by the map.

Two areas of Jacksonburg lie far removed from the main limestone belt (fig. 9, 6, 7). These small patches are down-faulted together with other Cambro-Ordovician limestones to form the Saucon Valley lowland, hemmed in by the crystalline highlands of the Reading Prong. The larger of the Jacksonburg areas lies half a mile northwest of Lanark. The bedrock crops out in road and railroad cuts, and is better exposed in two small quarries. The northwest margin of this area is very poorly known, but it is believed to be in fault contact with the crystallines of South Mountain. Faults also bound the area throughout most of the remainder of its extent. The second area of Jacksonburg in Saucon Valley is known only from two small outcrops on the banks of Saucon Creek north of Saucon Hill. The size and marginal relations of this area are very poorly known, but it is presumed to be in fault contact with the crystallines of Saucon Hill on its south side.

In Lehigh County the Jacksonburg formation is not topographically distinctive. There is a tendency for the argillaceous limestones of which the formation is composed to be less soluble than the underlying magnesian limestones, and for the Jacksonburg formation to form a surface slightly above the rest of the limestone lowland. This characteristic is, however, poorly defined, and is nowhere distinctive enough to be of much assistance in geologic mapping. The Martinsburg shales which flank several of the Jacksonburg areas on the northwest are quite insoluble, and form hills that rise from 100 to 300 feet above the Jacksonburg level. In some parts of the county the break in slope at the base of the shale hills indicates clearly the contact between the Jacksonburg and Martinsburg formations. In other places the slopes between the shale upland and the limestone lowland are gradual and irregular so that the topography is of little assistance in the accurate location of geologic contacts. This is especially true where glacial drift mantles much of the pre-Illinoian topography.

Lithologic characteristics.—The Jacksonburg limestones are normally distinctive, and separable on the basis of lithology alone from the underlying limestones of the Beekmantown and Allentown formations, and from the overlying Martinsburg shales. At a few places limestones in the lower Jacksonburg closely resemble certain phases of the Beekmantown, and may cause confusion in properly designating the beds, especially where the exposures are not extensive. Such confusion in the mind of the geologist is the exception, however, rather than the rule in Lehigh County. The upper part of the Jacksonburg is a very shaly limestone, which may resemble slate. Where any doubt exists as to the designation of these upper beds, a test with dilute acid will always show effervescence of unweathered Jacksonburg shaly limestone, whereas the Martinsburg shales are non-calcareous and do not effervesce.

In Lehigh County two facies of the Jacksonburg formation are recognizable. The lower part of the formation is known by the quarryman's term "cement limestone," whereas the upper part is designated "cement rock." These facies are distinguishable from each other in some parts of Lehigh County, but elsewhere they lose their identity. Separate mapping of the facies was not attempted because inadequate exposures, combined with extremely complex structure, promised to introduce such considerable errors as to nullify the value of the lines drawn. The following description of the two facies of the Jacksonburg is taken from the Northampton County report[3] where they were more readily recognizable and were separately mapped.

> The lower part of the formation, the cement limestone facies, is a fossiliferous high-grade, non-dolomitic limestone which varies in color from dark gray to black. It is normally crystalline, the crystals ranging in size up to about three millimeters. In places, however, the texture is so fine that the individual crystals cannot be distinguished with the unaided eye. The bedding of the cement limestone in unweathered exposures is massive, visible bedding planes being spaced from one foot to as much as fifteen feet apart. In weathered exposures, however, solution has emphasized the presence of minor or incipient bedding planes, so that the beds may be as thin as an inch. The cement limestone is relatively competent as contrasted with the overlying cement rock. Mountain-building stresses, to which the region has been subjected, have produced complex folds but unaccompanied by much flowage, shearing, or intricate, small scale distortion. The fossils in the cement limestone are normally visible only on weathered surfaces, but they are not distorted beyond recognition as they commonly are in the cement rock.
>
> The cement limestone is readily dissolved by meteoric waters, so that very few cobbles or fragments of it are to be found in the surface soils.

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[3] Miller, B. L., Fraser, D. M., and Miller, R. L.: op. cit., pp. 251-253.

> Clay pockets are visible in some of the quarries. The upper rock surface is an irregular solution surface, but solution and weathering do not progress to depths exceeding a few feet, except along major joint and bedding planes.
>
> Overlying the cement limestone facies . . . is a more argillaceous facies of the Jacksonburg, to which the name cement rock facies has been applied. The gradation from the cement limestone to the cement rock is by means of intercalation. Argillaceous limestone beds become more abundant in the upper part of the crystalline cement limestone until they exceed the crystalline beds in quantity and thickness. In some of the cement quarries, the transition is quite abrupt so that it is possible to select by eye an exact horizon below which the cement limestone is clearly dominant and above which the cement rock facies prevails. . . . Commonly the transition zone may extend over fifty feet. Occasional crystalline high-lime beds are present even higher, and argillaceous beds even lower. Where exposures are not continuous, this introduces a considerable source of error in the separation of the two facies on geologic maps.
>
> The cement rock is a black, fine-textured, argillaceous limestone, superficially bearing a closer resemblance to slate than to limestone. Slaty cleavage is irregularly developed, commonly obscuring or entirely obliterating the traces of the original beds. Despite its approximation to the physical characters of slate, the cement rock is distinguishable from the Martinsburg slates by its deep, velvety-black luster and by the absence of color bands. A test with dilute acid will also invariably distinguish the two, as the Martinsburg slates are non-calcareous, and the cement rock seldom carries less than fifty percent $CaCO_3$. In many quarry faces, veins of calcite and of quartz are present, usually paralleling the bedding in the lower cement limestone facies and the slaty cleavage in the upper cement rock facies. They are much more numerous in the cement rock facies, locally being so abundant and so closely spaced as to give the rock the appearance of a layer cake.

The only important variation to be noted in Lehigh County from the typical lithologies described above is a tendency for the lowermost beds of the formation to be light in color, and even to appear slightly dolomitic. Inasmuch as there is here no striking unconformity at the base of the Jacksonburg, this causes the Beekmantown-Jacksonburg contact to be much more obscure in Lehigh County than in Northampton County.

The cement limestone facies of the Jacksonburg is well exposed in a series of small quarries on the south side of U. S. highway 22, one mile east of Fogelsville. Another typical exposure of this facies occurs in a quarry in the south part of Hokendauqua about 200 yards west of the junction of the Ironton R. R. tracks with the main line of the Lehigh Valley R. R. The cement rock facies of the Jacksonburg may be seen in many of the large cement quarries. The active quarries of the Whitehall Co., the Giant Co., and the Ormrod plant of the Lehigh Co. are good examples.

Thin beds of altered volcanic ash are intercalated with the Jacksonburg limestones at several localities. Where metamorphism has not been great these appear as thin seams of sticky yellow or brown clay parallel with the bedding of the limestone. In a few places the ash beds have been altered further to a slippery micaceous shale, which is sticky when moistened. These shaly ash beds normally show a well-developed cleavage at a considerable angle to the bedding.

The source of the volcanoes whose eruptions during Jacksonburg time supplied the material for the ash beds is not known. Beds of volcanic ash furnish excellent horizon markers, where correlations based on thickness and spacing of the beds may be checked by paleontologic or other means. In Lehigh County the paucity of paleontologic evidence and complex folding and faulting make corroboration or correlations based on ash beds uncertain. No correlations are advanced although in some places the number and spacing of the ash beds is suggestive.

Ash beds in Lehigh County are normally noticed only in quarry faces. This is because quarries furnish the only localities where fresh bedrock is well enough exposed to distinguish clay seams formed by weathering of limestone by waters working downward along beds or joints from true altered volcanic ash beds. Ash beds in Lehigh County range in thickness from fractions of an inch up to three or four inches. Ash beds have been observed by the writer in the following localities:

Localities of altered volcanic ash beds

1. Coplay Cement Co. quarry in West Coplay. Two thin clay seams in south quarry face, 20 feet apart. Upper one a questionable ash bed. In cement limestone facies.
2. Abandoned quarry along Lehigh Valley railroad tracks one mile north of Coplay. Four ash beds spaced a few feet apart in southeast corner of quarry. These are also visible in southwest quarry face. In cement limestone facies.
3. Abandoned quarry of Giant Cement Co. 1.1 mile southwest of West Coplay. Two ash beds in west face of quarry. In cement limestone facies.
4. Abandoned quarry of Giant Cement Co. 0.8 mile southwest of West Coplay and 0.3 mile northeast of no. 3 above. Bed 6 inches thick in west face possible ash bed. In cement limestone facies.
5. Abandoned quarry of Giant Cement Co. 0.9 mile west southwest of West Coplay and 0.3 mile northwest of no. 4 above. Three probable and one possible ash beds spaced at 105 feet, 10 feet and 8 feet apart. In cement limestone facies. Upper three may correlate with ash beds of no. 2 above.
6. Lehigh Cement Co. quarry at Fogelsville. Two ash beds high up in northeast corner of quarry. In cement rock facies.

Paleontologic characteristics.—The Jacksonburg limestone is sparingly fossiliferous in Lehigh County. This is due partly to the fact that the beds have been so much deformed by rock flowage, shearing, and development of slaty cleavage that most of the fossils have been completely obliterated. It is probable, however, that there never were as many fossils in the formation here as in the less argillaceous beds of the type locality in northwestern New Jersey. The muddy seas of Lehigh County were not especially favorable to marine life, and especially to the larger forms that flourished at this time in northern New Jersey and central New York.

Fossils may be found in the Jacksonburg at several localities in Lehigh County although generic and specific identification is usually difficult or impossible because of the poor state of preservation. They are normally visible only on weathered surfaces. The writer has found undoubted fossils in the Jacksonburg at the following places:

Jacksonburg fossiliferous localities

1. Small abandoned quarry in north Coplay, 100 yards southeast of abandoned plant of Coplay Cement Co. Lower Jacksonburg beds in fault contact with Beekmantown. Contain branching stem-like bryozoa.

2. Quarry in south Hokendauqua in corner formed by Ironton R. R. and Lehigh Valley R. R. tracks. Crinoidals and fragmentary bryozoa in lowest beds exposed.
3. Whitehall Cement Co. quarry in Cementon. The large bryozoan *Prasopora orientalis* and other small fragmental bryozoa and brachiopods were visible in stripped weathered beds at top of southwest face of quarry (April 1937).
4. Giant Cement Co. quarry in Ormrod. The large bryozoan *Prasopora orientalis* was present in abundance in stripped weathered beds on the surface at southeast corner of quarry (Sept. 1934).
5. Abandoned quarry one block north of main right angle crossroads in Fogelsville. Crinoidals.
6. Abandoned quarry 100 yards south of U. S. Highway 22 and one mile east of Fogelsville. Of four small quarries in this vicinity the one nearest the gravel road and nearest the crest of the hill just east of the gravel road contains small crinoidals.
7. Large abandoned quarry half a mile north of Breinigsville. Small brachiopods, stem-like bryozoa, and crinoidals in upper beds on north side of quarry.

None of the localities listed above offer good fossil collecting. At Jacksonburg, New Jersey, Weller[4] found 64 species of well-preserved fossils, and 10 more species have since been recorded from this section. Studies in New Jersey and in Northampton County have shown that *Prasopora orientalis* seems to be confined to the upper part of the Jacksonburg.[5] In Lehigh County the two occurrences of *Prasopora orientalis* that have been observed are both in the upper or cement rock facies of the formation. The branching bryozoa, crinoidals, and small brachiopods that have also been found in Lehigh County were in most cases in the lower or cement limestone facies. This is not stratigraphically significant, however, for these delicate forms would have been destroyed by the shearing and development of cleavage in the less competent rock facies. This is clearly shown by the fact that branching bryozoa do occur with *Prasopora orientalis* in some crystalline beds included in the upper Jacksonburg at the Whitehall Cement Co. quarry. In general, however, *Prasopora* is the only fossil that was sufficiently chunky to survive the rock flowage and shearing which most of the upper Jacksonburg beds have been incapable of resisting.

Thickness.—The Jacksonburg formation varies greatly in thickness from place to place in Lehigh County. It is completely absent in many places where its presence is expectable. Elsewhere its thickness is much less than the maximum, which is developed in the eastern part of the county. In much of the Egypt-Cementon-Ormrod region (fig. 9, 1) the lowest Jacksonburg beds are not exposed. However, in a quarry one mile west of West Coplay, 225 feet of the cement limestone facies were measured. The lowest beds in the quarry are believed to be very near the base of the formation. In the quarry of the Lawrence Portland Cement Company in the borough of Northampton, just across the Lehigh River from Cementon, 365 feet of beds within the cement rock facies are present. In this quarry the highest beds are very near the top of the formation, but the lowest beds exposed are an unknown distance above the top of the cement limestone facies. At its maximum the thickness of the Jacksonburg in eastern Lehigh County is therefore believed to be not less than 600 feet, and it is probably not over 700 feet thick.

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[4] Weller, Stuart, The Paleozoic Faunas—Report on Paleontology: New Jersey Geol. Survey, vol. 3, 1903.

[5] Miller, R. L., Stratigraphy of the Jacksonburg Limestone: Geol. Soc. Am. Bull., vol. 48, 1937, pp. 1687-1718.

In the Fogelsville area also (fig. 9, 3) it is thick. Faulting and complex folding make reliable estimates difficult, even in the perfectly exposed beds in the Lehigh Cement Co. quarry. In the other Jacksonburg areas, the formation is thinner, and it thins to zero at many places along the limestone belt. There is no apparent uniformity in the changes in thickness.

Name and correlation.—The dark-colored argillaceous limestones of Lehigh County have been variously designated in the past, beginning with Rogers' name Matinal Argillaceous Limestone in the Geology of Pennsylvania, 1858. In recent years the name Leesport has been used by Stose and Jonas[6] for these beds whereas Jacksonburg has been applied by Behre[7] and the writer.

In 1937 the writer showed that the argillaceous limestones of Lehigh County are continuous with those of Northampton County, where paleontologic and lithologic evidence supports a correlation with the middle and upper part of the Jacksonburg of New Jersey.

The paleontologic basis for correlation of the Lehigh County beds is scanty. Little stratigraphic value attaches to the presence of the small brachiopods, stem bryozoa, and crinoidals. *Prasopora orientalis,* however, is restricted to the upper part of the Jacksonburg throughout northern New Jersey and Northampton County. Its presence in a similar position in Lehigh County is considered strong evidence that the cement rock and the underlying limestone maintain approximately the same age relations as they do farther east. Lithologic and stratigraphic evidence is opposed to a correlation of these beds with the Leesport of Lebanon County. The Leesport limestone is unfossiliferous, so that no paleontologic basis for a correlation exists. The name Jacksonburg is therefore adopted for the Lehigh County limestones. The very useful names cement limestone and cement rock, proposed by B. L. Miller,[8] have been retained to differentiate the contrasting facies of the lower and upper parts of the formation.

Stratigraphic relations.—The Jacksonburg limestone may be seen in contact with older limestones at several places in Lehigh County. Several of these are fault contacts that supply little stratigraphic information, but others are normal contacts. The list below includes all visible contacts between the Jacksonburg and older limestones known to the writer:

Jacksonburg-Beekmantown contacts

1. Ledge along private concrete road of Giant Cement Co. 100 yards east of mill. Normal fault.
2. Quarries of Lehigh Stone Co. 0.6 mile southwest of Ormrod and south of Ironton R. R. tracks. Fault contact occurs in west end of westernmost

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[6] Stose, G. W. and Jonas, A. I., Ordovician shale and associated lava in southeastern Pennsylvania: Geol. Soc. Am., Bull., vol. 38, 1927, pp. 505-536.

[7] Behre, C. H., Jr., Slate in Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 16, 1933.

[8] Miller, B. L., Allentown Quadrangle, Mineral Resources: Pennsylvania Topog. and Geol. Survey, Atlas 206, 1925.

Chart showing names that have been applied to the argillaceous limestones lying between the Beekmantown limestone and the Martinsburg shale in Lehigh County.

Where a ? is inserted in the chart, the age designation was not given or was not precise.

G. M. Kay Mohawkin standard column 1937		H. D. Rogers 1858	Frederick Prime 1883	E. T. Wherry 1909	F. B. Peck 1911	B. L. Miller 1925	G. W. Stose and A. I. Jonas 1927	C. H. Behre, Jr. 1933	R. L. Miller 1937 and R. L. Miller, this report
TRENTON	Gloucester								
	Collingwood								
	Cobourg								
		?	?		?	?			
	Sherman Fall	Matinal Argillaceous Limestone	Trenton Limestone	Nazareth Cement Rock	Lehigh Limestone	Cement Rock	Leesport Limestone	Jacksonburg Limestone	Jacksonburg Limestone Cement Rock Facies
	Hull								
	Rockland								Cement Limestone Facies
						?			?
BLACK RIVER	Chaumont			Nisky Formation	Nazareth Limestone	Cement Limestone			
	Lowville								
	Pamelia								

quarry near water level and crosses floor of easternmost quarry. Thrust fault.

3. Western of the two small quarries near center of triangular area bounded by roads 1 mile southwest of Ironton. Fault.
4. Small quarry 0.3 mile south of Fogelsville plant of Lehigh Cement Co. and 0.1 mile north of U. S. Highway 22. Normal contact.
5. Quarry 1.3 miles northwest of Trexlertown and 1.5 miles south of Fogelsville on spur of hill south of large abandoned iron pits. Normal contact.

In the quarry near the Lehigh Cement Co. (no. 4 in list) the basal Jacksonburg beds overlie the Beekmantown dolomitic limestones in apparent conformity. Although the upper beds in the quarry are clearly Jacksonburg and the lower beds Beekmantown, the exact contact is obscure. Near the east end of the quarry the contact was recognized by lithologic change and corroborated by the finding of a few conglomeratic pebbles of the Beekmantown in the lowest Jacksonburg bed. The quarry between Trexlertown and Fogelsville (no. 5 in list) is somewhat less obscure, with a transition zone 18 inches thick between beds of Jacksonburg lithology and beds of Beekmantown lithology (pl. 21, A). This is interpreted as reworked material and is included in the Jacksonburg, the contact being drawn below this zone.

The evidence from these two localities indicates that the lowest Jacksonburg seas advanced across Lehigh County upon a surface of low relief, and the Jacksonburg rests with only slight disconformity upon Beekmantown limestones, even though all of Chazy and Black River time are represented in the hiatus between the two formations. This contrasts with the nature of the same contact in New Jersey and eastern Northampton County, Pa., where a prominent basal conglomerate is present at some localities, and evidence of deep erosion of the Beekmantown in pre-Jacksonburg time is abundant.

Only one exposure has been found in Lehigh County where the Martinsburg shales may be seen directly overlying the Jacksonburg limestone. This is located one mile north of Fogelsville along the secondary road on the east side of Hassen Creek. At this locality the non-calcareous black Martinsburg shales are tightly in contact with black cement-rock beds of the Jacksonburg (pl. 20, B). The strike and dip of the Jacksonburg beds is N.37°W., 55°NE.; of the Martinsburg beds N.66°E., 13°NW. There is a slight amount of folding of Jacksonburg beds beneath the contact, perhaps due to drag, but there is no other evidence suggestive of faulting. The writer believes that this exposure represents an original unconformable contact, but that minor slippage along the contact has emphasized the angular relations between the beds. At dozens of other localities where the Jacksonburg beds are exposed close to the base of the Martinsburg shales, there has been no sign of lithologic gradation from the cement rock to a shale lithology. The Martinsburg shales thus appear to overlie the Jacksonburg unconformably, but it is doubtful that the large degree of angularity visible in the contact (pl. 20, B) at Fogelsville is entirely due to unconformity.

At one locality in Lehigh County the Martinsburg shales may be observed lying on Allentown limestone. This exposure is in a large quarry in the north part of Limeport in Saucon Valley. Here there seems to be no possibility of faulting. The Martinsburg shales lie on an irregular erosion surface of Upper Cambrian dolomitic limestones, with the Beekmantown and Jacksonburg beds missing (pl. 23, B).

The major stratigraphic problems of the Jacksonburg formation in Lehigh County are two. 1. Was the Jacksonburg limestone deposited over most of Lehigh County and later eroded in places, or was it deposited only in isolated basins never much more extensive than suggested by the present patchy distribution of the formation? 2. Is the unconformity at the base of the Martinsburg shales at Limeport the same as the unconformity at Fogelsville, or is it rather due to pre-Jacksonburg erosion, with the Jacksonburg not deposited at Limeport?

The first problem may be answered with some assurance for the main limestone belt of Lehigh County. The evidence of unconformity at the base of the Martinsburg previously cited, and the absence of any lithologic changes in the Jacksonburg which would indicate proximity to shorelines, combine to indicate that the Jacksonburg was deposited over most of central Lehigh County. It appears to have been thicker to the east than it was on the western side of the county. The Jacksonburg was later warped above sea level and irregularly eroded, in some places very little but in others completely removed. The Martinsburg shales thus rest in places on upper Jacksonburg, elsewhere on lower Jacksonburg, and in some parts of the county the Jacksonburg is now completely absent and the Martinsburg shales rest on the Beekmantown limestones. This interpretation is illustrated by the series of diagrams in Figure 10.

The second problem is difficult of solution because the Jacksonburg is now preserved only in two small fault blocks in Saucon Valley. There is thus scanty evidence of its nature and of its former relations to overlying and underlying formations in this region. The lithology of the formation is essentially similar, however, to its development in the main Jacksonburg belt, and there is no evidence of the proximity of shorelines of the Jacksonburg sea. Although the Jacksonburg overlies the Beekmantown with slight disconformity in the central part of Lehigh County, there is a strong unconformity, representing hundreds of feet of erosion, beneath the Jacksonburg in western New Jersey. It seems likely that this change taking place from central Lehigh County eastward would also take place in a southeast direction, more directly toward Appalachia. This evidence is inconclusive, but it seems to favor the view that the Beekmantown at Limeport was eroded in pre-Jacksonburg time. The Jacksonburg limestones were then deposited, but were probably thinner than in the central part of the county. Renewed uplift, warping, and erosion removed all of this Jacksonburg mantle at Limeport, and more of the underlying magnesian limestones, but left remnants of the Jacksonburg which were later downfaulted to form the areas at Lanark and Saucon Hill. If this interpretation is correct the Limeport unconformity represents merged pre-Jacksonburg and pre-Martinsburg unconformities, the comparative importance of which is entirely conjectural.

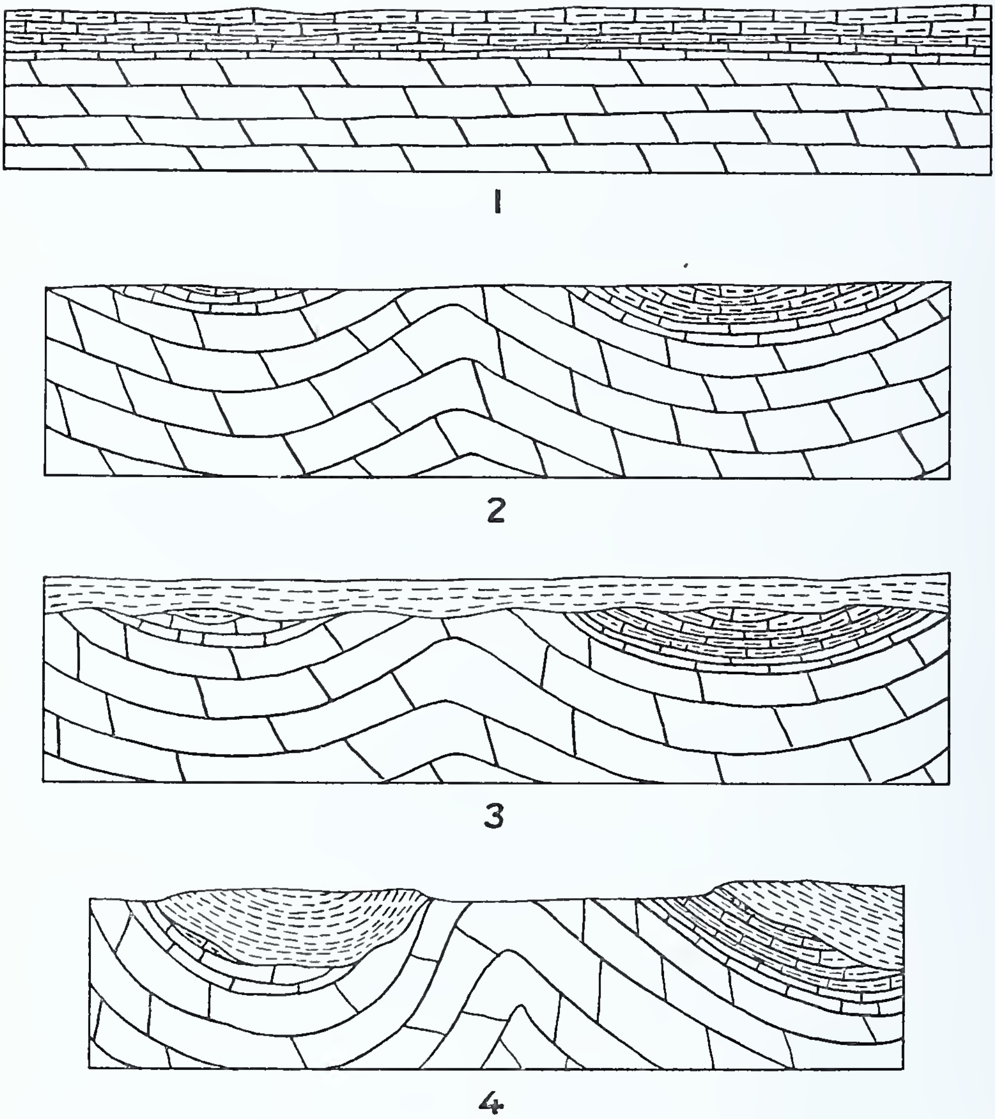

Figure 10. Series of diagrams illustrating the reason for the patchy distribution of the Jacksonburg limestones in Lehigh County.

The history of pre-Martinsburg Mohawkin time may be summarized as follows, in line with the interpretations advanced above. Following the deposition of the Beekmantown limestones, a long period covering all of Chazy and Black River time elapsed during which Lehigh County stood above sea level and received no deposits. The central and northwestern parts of the county were low lying and suffered no appreciable erosion, but southeastern parts of the county were probably eroded deeply. In lower Hull time the Jacksonburg seas advanced from the northeast, and deposited limestones which were at first relatively pure but later quite argillaceous. These Jacksonburg deposits probably formed a continuous mantle over the entire county, thicker however to the northeast than in southern and western sections. In Sherman Fall time the Jacksonburg seas retreated, the region was up-warped and irregularly eroded. In places all of the

Jacksonburg and some of the underlying beds were removed; elsewhere there was little denudation. Later in Trenton time the county was again submerged beneath the waters of an inland sea, and the earliest Martinsburg shales were laid down on a sea floor whose underlying bedrock varied from Jacksonburg limestones to Allentown limestones.

Local details.—A large quarry 0.7 mile north of Breinigsville supplies one of the problem localities in the county. Along the north quarry face the beds resemble lower Jacksonburg limestone, though somewhat more massive and lighter in color than normal. Crinoidals and small bryozoa are abundant in some of these beds, which strongly supports the Jacksonburg designation. The floor of the quarry is composed of massive and partly dolomitic, unfossiliferous limestones more closely resembling the Beekmantown. The lithologic change between the two rock types is slight, however, and no horizon is exposed that appears to represent a contact between the two formations. If the contact is indeed present in this quarry, then the tendency for the Beekmantown-Jacksonburg contact to be obscure in Lehigh County has here reached the stage where it is no longer recognizable.

Several small areas of Beekmantown are included within the Jacksonburg areas. These are in most cases in fault contact with the surrounding limestones. Several of these are shown on the geologic map but others are so insignificant that they were not included in the mapping. One of these deserves special mention. The Beekmantown beds were uncovered by construction work in the ditch along the highway ascending the hill south of Egypt and 0.2 mile east of the mill of the Giant Cement Co. The dolomitic beds were flat-lying, and could be seen to have been thrust northward over upper Jacksonburg beds. Although the exposure is no longer available, the occurrence is of interest as a clear case of a low-angle thrust fault, on which there must have been several hundred feet of displacements as a minimum.

MARTINSBURG FORMATION

By Bradford Willard

The younger Ordovician formations, like the limestones, are of a sedimentary origin. That is to say, they were deposited layer on layer in water. But, unlike the limestones, they are not precipitates. Examine them, and they are seen to consist of various sized particles of mineral matter derived from older rocks which have been broken up by weathering and erosion. The pieces were swept away by agents of transportation, chiefly moving water, and laid down in layers by that same agent. Such rocks are called clastic sedimentary rocks. Chiefly they are conglomerates, sandstones, and shales. In Lehigh County the second and third are commonest. Of the sandstones, many are truly arkoses or more correctly graywackes. They are highly feldspathic. Much of the original shale has been altered to slate through processes of metamorphism.

The Upper Ordovician and Lower Silurian in Lehigh County form a sequence of non-calcareous clastic sediments which may be duplicated in other parts of the State, but in some localities the succession is somewhat different from that in Lehigh County. Different formational names are applied and different interpretations of origin given. These need not concern us here particularly.

The Martinsburg formation crosses Pennsylvania in a wide band from New Jersey on the eastern to Maryland on the south-central border. The type locality is at Martinsburg, West Virginia where it was named and first described in 1891 and 1894. Since then the term has been applied in Pennsylvania and adjoining States. But prior to the general use of the term, the vast, thick mass of Ordovician shales and sandstones was studied and described by several geologists either in general or for restricted localities.

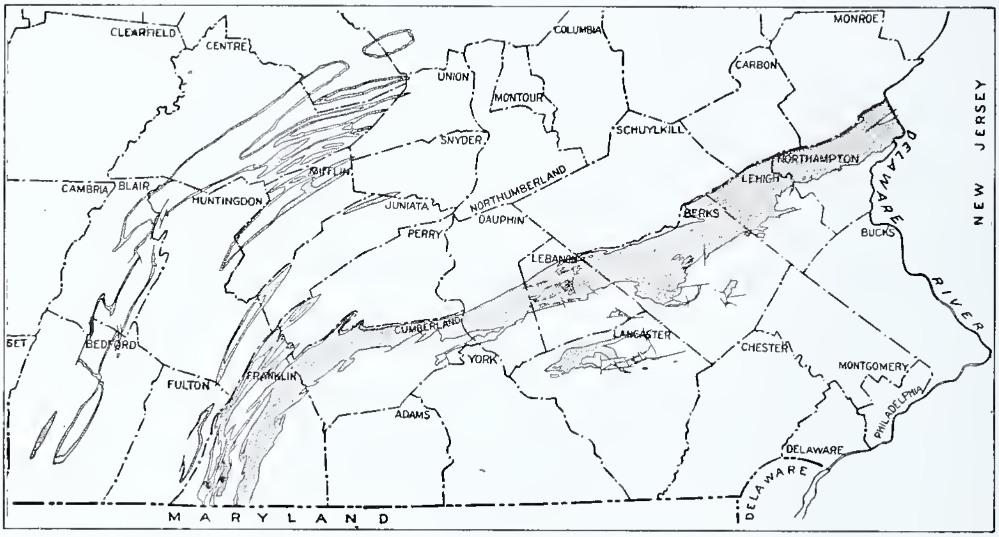

Figure 11. Sketch map showing distribution of Martinsburg and other Ordovician clastic sediments in Pennsylvania.

The First and Second Pennsylvania Geological Surveys recorded some broad generalities regarding the Martinsburg. They referred it to similar shales in New York called the Hudson River and Utica. In 1883 appeared the Second Survey's report on Lehigh and Northampton Counties. R. N. Sanders, one of the co-authors of that account, described the slate belt in Lehigh County. Both the Second and First Surveys were generous in allowing some 6,000 feet for the total thickness of the group. They generally recognized that it consists of two parts, an upper sandy, and a lower shaly or slaty division. After the termination of the Second Survey, toward the end of the century, a few other papers appeared which touch upon the Martinsburg in Lehigh County. Notable are the accounts by F. B. Peck and T. N. Dale, although they contributed little that was not already known from the works of the earlier surveys.

The present Topographic and Geologic Survey has taken up the questions of the Martinsburg in the Slate Belt of Lehigh and Northampton Counties more thoroughly. B. L. Miller's Allentown Quadrangle report is the first of the more modern accounts. It included only a small part of the county, but ascribed a thickness to the Martinsburg of only 3,000 feet. Miller subdivided the group ("formation") into three parts. Thus he departed from the ideas of the earlier Survey workers who used a two-part subdivision. Miller maintained that these should be designated as a lower and upper shaly or slaty member and a middle sandy member.

In 1927 C. H. Behre, Jr. described the slate belt in a State Survey report, and in 1933 amplified this with a report on the slate of the entire State. This is a monumental work and by far our most detailed report on the slate and other parts of the Martinsburg in Lehigh County. Behre adhered to the three-fold interpretation of the Martinsburg and supported his belief with excellent arguments, although he generously admitted that the supporters of the two-fold interpretation had certain points in their favor. Behre assigned the almost unbelievable thickness of 11,800 feet to the Martinsburg of the Slate Belt. He subdivided it as follows:

Upper Martinsburg: blue-gray and brownish, widely banded, partly carbonaceous slates and clay shales. 2,600 ft. (?)

Middle Martinsburg: brown, calcareous, locally conglomeratic sandstones and sandy shales with occasional red and green shales; ocherous shales near base. Pulaski fauna at top, Eden at base. 4,200 ft.

Lower Martinsburg: thinly-banded blue-gray slates and fine-grained, calcareous sandstones; some red beds. Lower Trenton (Upper Black River?) fauna at base. 5,000 ft.

Behre supported his belief in the tripartite interpretation primarily upon structural data. In his Plate 34 (Bulletin M 16) he drew a north-south structural section (B) at a point west of Slatington. The outstanding feature of this section in support of the tripartite interpretation is that it shows the northern slate member overlying along its southern edge, the middle sandy member. If this is true it is curious that Behre mapped no upper slate remnants on the sandstone area to the south.

Of other accounts that touch upon the Martinsburg in the eastern part of the State, some have been published, some are in manuscript form. In the latter class are reports by Freeman Ward. Through a misunderstanding, Professor Ward and the writer covered overlapping Martinsburg assignments for the State Survey. When this was discovered, a conference was arranged and Professor Ward kindly turned over his data to the author, who, with the consent of the State Geologist, has used it liberally in this report. Specific credit may not always be given Professor Ward where due, but the writer takes this opportunity to express his thanks and appreciation of the spirit in which Professor Ward's results were handed over to be used as might be seen fit.

The most significant paper recently published in support of the two-fold interpretation as against the three-fold is that by G. W. Stose in 1930. Mr. Stose worked from the south northeastward into Lehigh County, and concluded, as had the First and Second Survey people, that the Martinsburg is two-fold. This is also the interpretation put upon it by Ward in his manuscripts and by the present author in a recent paper. It is not necessary here to enter into the details of the controversy, but more will be said of it subsquently. It is enough to say that the general impression of the two-fold group is that the Martinsburg area is actually a great syncline or synclinorium with the sandy member lying along the axial region. They support their contention by structural and paleontological data. All of these workers tend to a belief in a thinner Martinsburg. The writer's own conclusion is that it cannot be much over 4,000 feet, and more probably is about 3,500 feet thick. Of this, the upper sandstone takes up perhaps 750 feet or a little more of the whole.

METAMORPHISM OF THE MARTINSBURG

From its type locality in Martinsburg, West Virginia, northeastward, the Martinsburg is chiefly unaltered sandstone and shale. However, in Berks, Lehigh, and Northampton Counties, it is altered by compression so that the shale is chiefly turned into slate. It is this change that is responsible for the Slate Belt. Yet the shales of the younger Paleozoic systems are not so altered in eastern Pennsylvania. This relative difference in degrees of alteration is laid to the fact that the Taconic Disturbance affected the rocks of eastern Pennsylvania near the close of the Ordovician period. Therefore, these rocks were more highly compressed and altered than later, post-Taconic formations, which were affected by the Appalachian Revolution alone. As the metamorphic effect of the Taconic hardly extends west of the Schuylkill, the slate belt is confined to the part of the State east of that river.

DISTRIBUTION

The Martinsburg formation of the Upper Ordovician is prominent in Lehigh County. Referring to the geologic map of the county, its distribution is at once apparent. It occupies a broad band crossing the northern half of the county in a northeasterly direction roughly parallel to the average strike of the beds. The northern boundary is delineated by the south slope of Kittatinny Mountain. The contact here with overlying beds is usually concealed, but it seems probable that it usually lies very near the 1,100- or 1,200-foot contour. Near this elevation the Bald Eagle conglomerate, which directly overlies the Martinsburg, has been found on Highway 29. This is near the change of slope of the mountain. The contact is lower down at Lehigh Gap on the Northampton County side, but the beds and the contact dip north. The northern trace of the Martinsburg is slightly sinuous, conforming to the small indentations or spurs of the mountain, as at Bake Oven Knob and Lehigh Furnace Gap.

The southern boundary of the Martinsburg is quite irregular and marks the contact of the clastic sediments with the underlying limestone. Entering the county in the vicinity of Cementon on the Lehigh River, the line wriggles westward and southwestward until it leaves the county about 2½ miles west of Breinigsville. While at first sight the sinuosity of this line seems to have neither rhyme nor reason, it will be seen when the discussion of the structural geology is taken up, that it has a very definite relationship to the dominant folds of the area. Thus, projections of shale onto the limestone areas mark synclines, and the limestone reëntrants into the shale are anticlinal in origin.

The Martinsburg is not of a uniform or monotonous lithology throughout, but has been differentiated into large units which are shown on the map. These consist of a middle sandstone and bordering shale bands. Extending across the extreme northern part of the county below the foot of Kittatinny Mountain is the northern band of shale or slate, one to three miles wide. Its northern boundary is coincident with that of the Martinsburg as a whole. Its southern border is fairly regular from Slatington on the Lehigh westward nearly to Lynnport, where it reverts sharply eastward, zigzags south about New Tripoli, and then continues westward as a sinuous trace to the county line south of Slateville. The second band of shale and slate forms the southeastern portion of the Martinsburg. Its western or northwestern boundary crosses the map in a crooked trace whose turns and curves follow closely those of the shale-limestone trace two to four miles to the southeast. The irregularities are attributed to the same causes as are those of the shale-limestone contact. Between the two shale and slate bands lies the medial sandstone strip. This enters the county on the east between Slatington and Laurys Station as a band about three miles wide, runs west half way across the county, then turns abruptly south in a sigmoidal curve and swings again west in the region south of Pleasant Corner. The strip broadens to a maximum width of nearly nine miles at the Berks County line, interrupted by small shale bands here and there.

The northern band of shale and slate is usually referred to as the "soft slate" belt, and the southern as the "hard slate" belt. These are quarrymen's terms and of no true geologic significance or standing.

TOPOGRAPHIC EXPRESSION

The northern part of Lehigh County which is underlain by the Martinsburg "formation" is a region dominated by low, rounded hills and rather ill-defined ridges. At first glance at the topographic maps, one has the impression of a confusion of small elevations separated by valleys in which the streams follow indefinite courses. However, a more careful examination of the maps shows that there is a development of low ridges, particularly in the sandstone-dominated area. These trend in a northeasterly direction and in this reflect the strike of the strata. Most pronounced of these is Shochary Ridge which extends from its invasion of the northwestern part of the county eastward for fully eight miles, beyond which it loses its identity. A good view may be had of this ridge from Bake Oven Knob. Along its flanks the stream pattern is clearly developed with reference to this ridge, as the valley of Ontelaunee Creek on the north and that of Kistler Creek on the south run parallel to the ridge. Toward the western end of Shochary Ridge is found the highest point of the Martinsburg in Lehigh County. The altitude is slightly over 1,060 feet. The lowest exposed Martinsburg is along the Lehigh River north of Cementon. This is approximately 320 feet above sea level. Therefore, the maximum relief for the Martinsburg is of the order of 740 feet. Yet, in general, the relief is considerably lower, for the shale hills of the northern slate belt have an average elevation close to 500 feet, while much of the area of the sandy Martinsburg rises to from 700 to 800 feet to the west near the Berks County line and some 400 to 700 feet on the east toward the Lehigh River.

Thus, topographically, the sandy Martinsburg presents a more rugged, hillier appearance, even to the development of fairly well-defined valleys and ridges, while the shaly (slaty) Martinsburg is expressed in a confusion of small hills and crooked valleys. In fact, so distinct is the topography of the two types of Martinsburg that it is nearly always an excellent check on mapping the contacts of the shale or slate with the sandstone.

The Martinsburg contact with the underlying limestone to the south is likewise sharply defined topographically. It amounts in some instances to a small scarp. There is an abrupt drop from the hilly Martinsburg terrane with maximum elevations of 600 to 700 feet to the flatter limestone valley at 400 to 500 feet above sea level. Likewise, the northern boundary of the region underlain by the Martinsburg is quite sharply defined. The soft beds of the northern slate belt pass under the massive sandstones, quartzites, and conglomerates of Kittatinny Mountain (called Blue, North or First Mountain in older reports). This mountain rises abruptly to elevations of 1,500 and 1,600 feet. Its fairly even crest forms a natural northern boundary to the county.

LITHOLOGY

Since nothing need be added to the already adequate and complete description of the slate beds in the Martinsburg as prepared and published by Dr. Behre, reference to them is best made by quoting from his 1933 report. It must be recalled that Behre strongly advocated the three-fold interpretation of the Martinsburg. His descriptions of what he called the lower and upper members are quoted rather fully. To begin with, he made the following general statement (p. 136):

> For practical purposes, the formation is best subdivided on a lithologic basis into a lower, a middle, and an upper part. The lower part is characteristically a banded clay slate, though there are also thin sandstone beds. The middle member contains sandy beds as its most typical facies, though some truly slaty beds are also found in it. The uppermost member is banded like the lower, but there is less sand and the individual beds are much thicker. The differences between these subdivisions are relative and in areal mapping the line between them is drawn with difficulty.

Following this general statement Behre amplified his findings and described minutely the lithology of the members of the Martinsburg "in the Lehigh-Northampton district" (pp. 137-146):

> *Lower Martinsburg member.* The lower member is generally a thin-bedded clay slate (shale?) or slate. Its prevailing colors are blue-gray or dark silvery gray near the "neutral gray k" of Ridgway's color chart, weathering to light yellowish-brown or buff. It contains layers that are alternately siliceous, sericitic or carbonaceous; the resulting banded character is the distinguishing feature of this part of the formation. This banding is shown on the fresh cleavage surface by streaks that are more silvery where siliceous, and grade more toward a black where carbonaceous. Individual beds are generally two or three inches or less in thickness, and never exceed a foot. Workable slate beds are not found throughout the lower Martinsburg, but occur only at certain horizons. Some good banded slate has been quarried . . . but it is not extensively worked. . . .

> The lowest part of this member consists along the Schuylkill of a dirty olive-green to grayish-brown micaceous sandstone and sandy shale; this is shown due west of Shoemakersville on the west bank of Schuylkill River in cuts of the Reading Railroad, and again in cuts of the same railroad about a quarter of a mile north of the West Leesport station. Followed eastward the lowest beds become more blue-gray and less shaly and correspondingly more sandy until they are predominantly blue-gray, rusty-weathering, locally calcareous sandstone, as in the hills two miles north of Maxatawny in the Slatington quadrangle. Still farther east, on the Lehigh and Delaware rivers the rock consists of blue-gray sandy shales and sandstones alternating in thin beds. Locally . . . there are also some red and green sandy shales. . . . There are also in the lowest member local lenses or beds of limestone up to three feet in thickness. . . .
>
> In the next higher part of the lowest member of the Martinsburg, the beds are more clayey, shaly, or slaty and are largely sericitized, and it is in these strata that the workable slate occurs. These slaty phases are . . . the "hard" slate. In this member there are also sandy strata, but sericitized, originally clayey layers predominate.

As remarked, so far as his description of the two belts of slate or shale goes, nothing important may be added to Behre's work. For the sandstone, some data should be introduced which were not mentioned by him. This is the sandstone which Willard and Cleaves named the Shochary after Shochary Ridge in Berks and Lehigh Counties. The unit has a thickness of 750 feet, or possibly somewhat more, as nearly as can be discovered in a region where structures are complex and sections none too well exposed. The thickness varies, since the upper surface of this, the highest Martinsburg unit, according to the two-fold school, may have been unequally eroded after the Taconic Disturbance. Of this sandstone, the upper 150 to 200 feet in Shochary Ridge are nearly free of the calcareous cement that is prevalent in the remaining, lower portion. The distinction between these two types can be readily made in most cases in the field by testing a piece of the fresh rock with dilute hydrochloric acid. It is the more resistant, lime-free, upper beds that form Shochary Ridge, our highest-standing area of Martinsburg in the county. That elevation is directly attributable to the presence of these resistant beds of sandstone. Not only is there a fairly sharp crest, but along both flanks at elevations of 600 to 700 feet there runs a flat bench which it is believed was caused by some firm or resistant beds at that elevation. Since this ridge is a syncline, such a bench argues for unusual symmetry in this region of unsymmetric folds.*

On the other hand the calcareous, that is, the calcite-cemented sandstone beds of the Shochary sandstone weather quite readily so that massive-appearing, fresh strata, break down easily under the elements. This limy part of the sandstone produces less prominent hills than Shochary Ridge. They are particularly well developed along the Berks-Lehigh County line south from Shochary, eastward into Low Hill and Weisenberg Townships and westward across Berks County.

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* This interpretation of the sandy, upper Martinsburg (two-part school) is not strictly in agreement with the suggestions made by Professor Ward. In fact, it is in this and this only, that he and I fail to see eye to eye in our individual interpretations of the group. Professor Ward believes that the non-calcareous beds with the Pulaski fossils are actually older than the calcareous beds. I am not inclined to accept this interpretation because, if the Pulaski fauna which appears in the crest of Schochary Ridge belonged in beds that are older than the sandstones which lie to the south and intervene between this ridge and the southern shale belt, the Pulaski fauna should reappear to the south near the southern slate. No trace of such a fauna has been found after careful search. This is negative evidence, to be sure. On the other hand, a few scattered fossils in the sandstones south of Schochary Ridge indicate that they are predominantly of Eden age. Apparently Stose (1930) had some such idea as mine; that is, that the calcareous part of the sandstone underlies the noncalcareous. However, from his sections, it is possible that he considered them more or less contemporaneous in age, as indeed they may be in Lehigh County. Author's comment.

Except for the presence of lime-carbonate, the two phases of the Shochary sandstone have little to distinguish them lithologically. Both are medium- to fine-grained, well-sorted, even-bedded arkosic sandstones or graywackes. Coarser or pebbly to conglomeratic beds are rare. Occasional bits of shale or *thongallen* are found. The bedding ranges in thickness from an inch or less to four or more. Particularly heavy bedding may be observed on U. S. Route 22 west of New Smithville at the county line and along the river south from Slatington. When fresh, the beds commonly are dark gray to grayish-brown, but they may weather darker or more commonly take on a brown, yellow-brown, rusty, or buff hue. Over a weathered outcrop the soil is commonly strewn with partially weathered sandstone chunks. Fossils occurring in the Shochary sandstone will be discussed subsequently. Interbedded with the sandstone are shale beds or lenses, usually dark, sometimes laminated, and commonly finely arenaceous.

The shale or slate of the Martinsburg is transitional with the Shochary sandstone. There is no sharp line of separation, merely a change in relative proportion of sandstone. The increase may be rather abrupt in a thickness of a few score feet. It can usually be detected better through topographic expression than from the poor sections available. For example, along the south border of the northern slate belt, the sandstones come in near the 600-foot contour west of Slatington. This lies near the change of topography from shaly lowland to sandy upland. The relation between the sandstone and the slate to the south is similar to that observed in the north.

Interbedded with the common lithologic types of the Martinsburg are certain other beds of less importance, but often of some stratigraphic value. Few of these are found in Lehigh County, however. Occasionally there is a thin conglomerate lens of quartz pebbles, fairly well-rounded, generally in a dirty matrix. Also there are a few conglomerates composed of fragments of limestone or bits of limestone and shale mingled. A thin bed of red shale occurs in the southwestern part of the Martinsburg area in the county. None of these occurrences is of great local significance. But, if they are considered in Berks County to the west, where their development is much better, they become important key beds in working out the structure. As such they help to understand the structural geology on a broad scale in Lehigh County. This will be seen in a subsequent discussion of the structures.

AGE OF THE MARTINSBURG GROUP

Determination of the age of the Martinsburg group is based upon its fossils, its correlation with beds of known ages elsewhere, the ages of overlying and underlying formations, and its relation to certain orogenic or tectonic activities which affected the group.

The age of the rocks next beneath the Martinsburg has recently been adequately determined by R. L. Miller. The Ordovician sequence in the county is:

- Bald Eagle conglomerate
- Martinsburg group
    - Shochary sandstone
    - Eden shales
- Jacksonburg limestone
- Beekmantown limestone

Miller's work on the Jacksonburg showed that its fossils in Northampton County tie it with the Sherman Fall member of the Trenton of New York, or its age is approximately middle Trenton. Miller demonstrated that the Jacksonburg, though here unfossiliferous, extends some distance into Lehigh County. He also showed that there is apparently a slight unconformity or hiatus between the Jacksonburg and the Martinsburg in eastern Pennsylvania. Recently Willard and Cleaves restudied the Ordovician-Silurian relations in Pennsylvania. In the course of their studies they suggested that the Bald Eagle conglomerate extends across northern Lehigh County, where it lies between the Martinsburg and the basal Silurian or Tuscarora sandstone. The Bald Eagle is probably of rather late Oswego age. It is separated by a disconformity from the top of the Martinsburg. Paleontologically, the youngest fossils in the Martinsburg occur in the Shochary Ridge sandstone on the ridge of that name. They are of Pulaski age. Such faunules were recorded by Stose and by Behre, and during the 1939 and 1940 field seasons the author collected the following from the crest of the ridge near the Lehigh-Berks County line:

"Crinoidea" columnals
Bryozoa, undet.
Hebertella sinuata Hall
Plectorthis plicatella Hall
Dalmanella multisecta (Meek)
Sowerbyella rugosa (Meek)
S. sericea (Sowerby)
Rafinesquina alternata (Emmons)
Strophomena sinuata (James)
Leptaena unicosta (?) (Meek and Wortham)
Rhynchotrema sp.
Clidophorus planulatus (Conrad)
C. sp.
Scenella (?)
Orthoceras lamellosus Hall
O. sp.
Ostracod, undet.

For comparison with the foregoing faunule from the Shochary sandstone, the following is inserted, being a composite of several small faunules collected along the eastern part of the ridge in the region south of Pleasant Corners, chiefly:

"Crinoidea" columnals
Hebertella sinuata Hall
Plectorthis plicatella (Hall)
Dalmanella multisecta (Meek)
Strophomena planoconvexa Hall
Sowerbyella rugosa (Meek)
Rafinesquina squamula (?) (James)
Ctenodonta levata (Hall)
Technophorus sp.
Orthodesma nasutum Conrad
Pelecypod, undet.
Liospira micula (Hall)
Orthoceras lamellosum Hall
Spiroceras sp.

Other fossils have been found in the lower portions of the sandstone down to and among the upper beds of the underlying shales (or slates). A detailed study was made along State Highway 100 from Fogelsville along Jordan Creek northward and so along Route 29 to the crest of Kittatinny Mountain. Most of these older fossils were collected in Low Hill and Heidelberg Townships. They are given below as a single faunule:

"Crinoidea" columnals
Dalmanella multisecta (Meek)
Strophomena sinuata (James)
S. sp.
Sowerbyella sericea (Sowerby)
Rafinesquina alternata (Emmons)
R. squamula (James)
Zygospira modesta (Hall)
Lophospira lirata Ulrich
Tetranota (?)
Gastropod, undet.
Orthoceras transversum Miller
Calymene granulosus Foerste

Traced eastward from Lehigh County, the Martinsburg shows little in direct correlation which will determine its age. It appears to tie in with the Utica, Frankfort, and Lorraine shales of New York. Westward, it passes into the unaltered portion of the group where fossils are more abundant and the age has been established quite accurately. The Martinsburg was folded during the Taconic Disturbance, but that tectonic event did not affect the overlying Bald Eagle. Therefore, the Taconic Disturbance is pre-Oswego but post-Pulaski, and so must further limit the highest Martinsburg.

STRUCTURES

Behre's final slate report is the most detailed account extant of the structural geology of the Martinsburg group in Lehigh County. It is at its best in dealing with the slate, but falls short of giving enough information on other parts of the group. One is constrained to believe that most of Behre's observations, judging from the text, figures, and maps, were taken from slate quarries, chiefly along the northern belt. Little appears to have been done on the southern slate belt and even less on the sandstone areas. But, it must be remembered that Behre's report was written primarily as an account of an economic product, and as such it was only natural that his observations should have been concentrated upon the stratigraphy and structural geology of the slate and particularly upon the parts of the county that produced the best and greatest abundance of slate. Observations elsewhere would have been more or less incidental. Although certain broader conclusions by Behre may appear to have been made upon inadequate evidence, much that he has said is highly important.

Thus, Behre discussed the structures of the slate quarries in great detail and described several score openings carefully. He wrote fully on the minor structural details, and it is suggested that the reader refer to Behre's 1933 report for the best and latest information on these lesser though important features. Behre's general north-south sections are of a different character, as also those published by Stose, and the manuscript sections drawn by Ward and others. All of these writers except Behre drew the northern slate as passing under the sandstone, but Behre reversed their order. Otherwise, all authors are in essential agreement on the broader structural features. The accompanying fig. 12 shows a comparison of sections. One is at a loss to understand why Behre drew the sections as he did. In reviewing the field, the author has particularly checked Behre's findings in the region of Slatington and Emerald and fails to find any evidence in support of Behre's ideas. On the contrary, the northern slate was observed to pass under the sandstones to the south. This is particu-

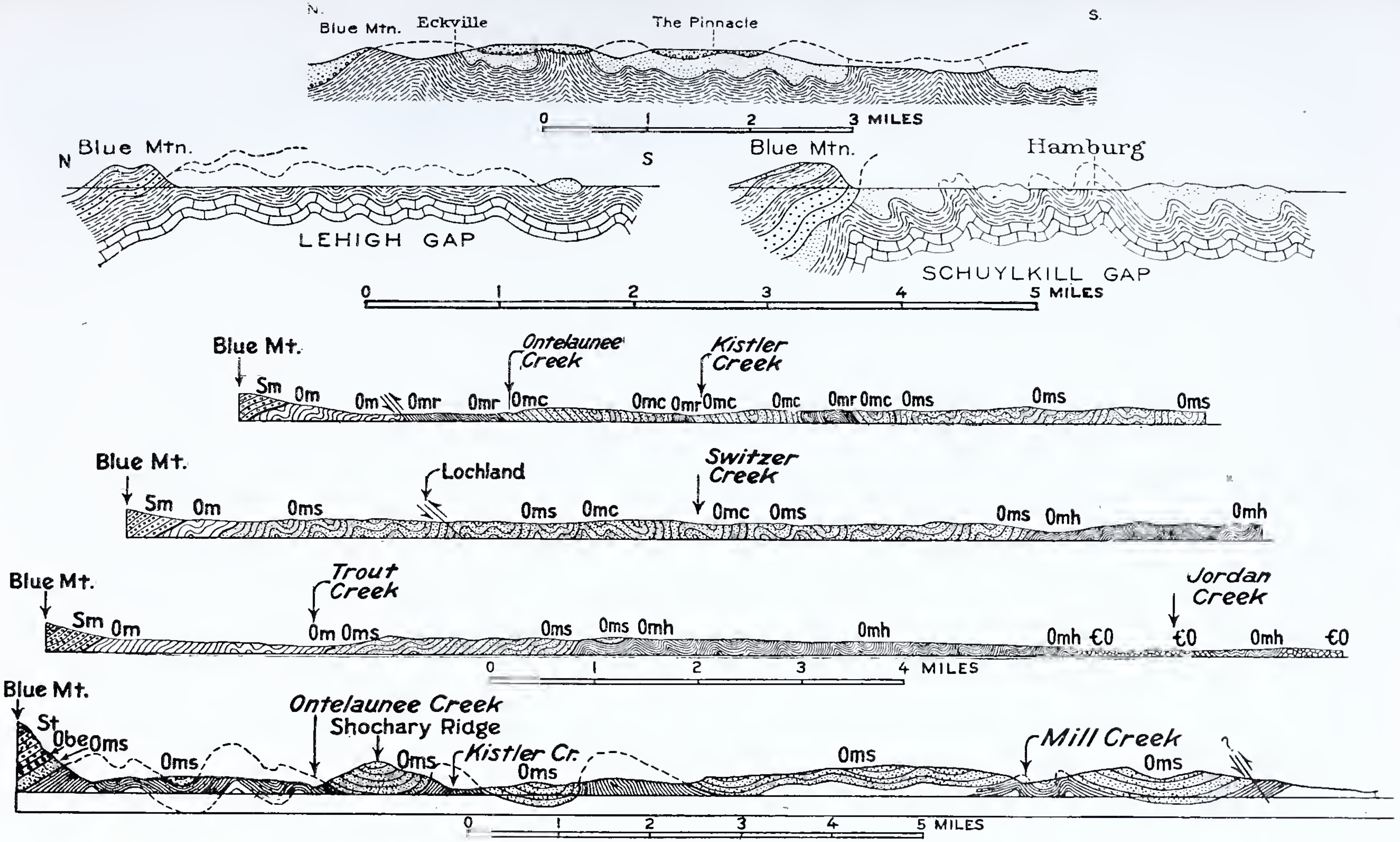

Figure 12. Sections after Stose and Behre compared with present interpretations.

Three uppermost sections are by Stose, next three by Behre, and bottom section by Willard.

larly well seen in the New York Tunnel quarry a quarter of a mile west of the Slatington railroad station and in quarries and along road and railroad cuts at Emerald. Unless there has been a great overthrust, for which no evidence was seen, the slate must be older than the sandstone. Nowhere has the writer seen the slate passing above the sandstone as indicated by Behre. Still further evidence was obtained in the northwestern part of the county in the vicinity of Lynnport. Here a small, elongated outlier of the sandstone occurs north from Shochary Ridge but separated therefrom by a shale area. Behre believed this sandstone to be a fault block and that the slate quarries to the north of it were in overlying beds. Again, the writer failed to find evidence that the slate passes beneath the sandstone. Furthermore, Ward and he found Eden fossils in some abundance in the beds north of the sandstone outlier (Behre called this the ''hogback'') whereas if the rock were younger than the sandstone, as Behre stated, the fossils could not have been as old as Eden, but must have been Pulaski in age. Still further confirmatory data were found in the vicinity of New Tripoli and Mosserville. The sandstone south of New Tripoli in Shochary Ridge (i.e., the Shochary sandstone) contains Pulaski fossils, but Eden fossils occur in the shales between New Tripoli and Mosserville.

The Martinsburg has a general east-west strike or trend of structures. Examination of the county geologic map will show that this is emphasized through the distribution of the two major slate or shale areas and the geographically median sandstone region. Note also within the sandstone region itself, several elongated shale patches whose major axes parallel the strike. Because the shale is older than the sandstone, these patches show where it is brought to the surface along anticlinal crests. These folds in turn have become valleys, through the soft nature of their rocks. Exemplifications are such valleys as run along the north and south flanks of Shochary Ridge. The valleys of Ontelaunee and Kistler Creeks respectively are cut in shale anticlines flanking the synclinal ridge. In opposition to the shale-bottomed anticlinal valleys, are the alternating, synclinal ridges. The topographic expression of these structures is a convenient means of checking their distribution.

Key beds are nearly absent in Lehigh County. In Berks County they are known, and some extend nearly to the Berks-Lehigh County line; two or three actually cross it. Typical examples are limestone conglomerate, limestone-shale chip conglomerate, red beds, and siliceous shales. By these key beds the structures can be further checked. Although they so seldom enter Lehigh County, their presence and use to the west clarify the establishment of structures that do cross the line.

Evidently, a combination of observations demonstrates the structures to the west, and such may be projected eastward. Another key to interpretive evidence must be mentioned, in this case taken directly from the geology of Lehigh County. Observe on the county geologic map the limestone-shale contact from Cementon and Egypt southwestward to the county line west of Breinigsville and Trexlertown. Next, note the line of the sandstone-shale contact west and northwest of the shale-limestone trace. One is impressed by two peculiarities. The limestone-shale trace is a sinuous line with here a westward-trending reëntrant of the limestone into the shale, there a shale point reaching into the limestone. The points and reëntrants are essentially aligned parallel to the strike of the beds. The second feature is that the curves, points, and reëntrants of the shale-limestone line are closely mirrored in twistings of the sandstone-shale line. The structural significance of these sinuosities is pertinent. Beginning with Shochary Ridge, and so southward, there is a general, gentle westward pitch to the folds. That is to say, the Martinsburg rises eastward and passes into the air above the underlying limestones. In such a situation it is a geologic axiom that along synclines the lower beds of a unit will be projected farthest into the region of older formations, here shale over limestone. Conversely, along the anticlinal axes, the older (limestone) will extend into the region of the younger (shale) beds as the reëntrants. Thus, along a contact that crosses the beveled, fluted ends of pitching folds, the points and reëntrants follow one another in a regular sequence. With these preliminary statements in mind, turn to a brief discussion of the principal structures. It must be clearly understood that because of local details, anticlinal or synclinal axes can rarely be drawn with more than approximate precision.

Northeast of Shochary Ridge there is a broad syncline extending west from the Lehigh River in the vicinity of Rockdale. This may conveniently be designated as the *Rockdale syncline.* Unlike most of the folded structures of the county, the Rockdale syncline plunges gently east. The sandstone rises westward, passes over the shales, and is eroded completely east and north of Lynnport. This sandstone area continues farther east where Behre mapped it in Northampton County. One and one-half miles southwest from the western tip of the Rockdale syncline is the eastern end of the ridge which Behre called the "hogback." This he considered a fault block, but others believe it to be a down-folded area. It is here referred to as the *Jacksonville syncline.* It plunges gently west. Once it may have been continuous with the Rockdale syncline, but it is now separated therefrom by an area of shale which possibly represents a cross-fold. The structure is obscure.

Shochary Ridge is the dominant structure of Lehigh County. This relatively sharp ridge with an altitude of 900 feet is a prominent topographic feature from the county line south of Wanamaker eastward to the region between Pleasant Corner and Lowhill. Beyond, to the east, it is less distinct and is lost about two miles west of Schnecksville. There, the lower part of the Shochary sandstone points a blunt finger over the shale. The structure may be called the *Shochary syncline.* That the structure continues well beyond is inferred from the presence of two small sandstone "islands" east and southeast of Neffs. Pulaski fossils have been found along the crest of Shochary Ridge as far east as Jordan Creek valley. Eden fossils were collected at points on the flanks, particularly along Jordan Creek near Lowhill. Paleontologically, this structure is established even without corroborative detail.

Separating Shochary syncline from the next sandstone is an arch which we shall call the *Ontelaunee anticline,* because the valley of Ontelaunee Creek is cut in its shales in the northwest corner of the county. This structure separates the Shochary and Jacksonville synclines and is lost at Lynnport, then reappears in the vicinity of New Tripoli between the Shochary and Rockdale down-folds. Its eastward path is next picked up in an isolated shale patch in the valley north of Flint Hill. Its position about Deibertsville is demonstrated by the reëntrant of shale into sandstone at this point. Beyond to the east, the structure has not been defined, though it probably passes through Rising Sun.

Kistler Creek valley, as remarked, is another anticlinal valley similar to that of Ontelaunee Creek. This structure may be referred to as the *Kistler anticline.* Well-defined at the county line, it is only vaguely understood east of Lynnville where all surface rock appears to belong to the Shochary sandstone. Possibly it is responsible for the small reëntrant 1¼ miles west of Schnecksville. A corresponding shale-limestone reëntrant continues the trend of this structure toward Schadts.

Kistler Creek valley is bounded on the south by an ill-defined ridge whose synclinal structure is attested by key beds in Berks County. These actually cross into Lehigh as some of the limestone-shale chip conglomerates. Apparently this is the same structure that is responsible for the attitude of the beds at the Pinnacle in Berks County. The conglomerates are parallel bands on opposite flanks of the fold here named the *Werley syncline* after Werleys Corner on its south flank. After the key beds disappear, it is but vaguely recognized across Lowhill Township, but may be responsible for the promontory of sandstone over the shale two miles southwest of Schnecksville, whence it probably curves slightly southeast to form the obtuse shale point over the limestone north of Siegersville.

The Werley syncline is south-bordered by a broad band of shale at Stines Corners, the *Stines anticline.* No well-developed valley follows its axis, although a branch of Stony Run is cutting headward along the belt. The structure is partially defined by red beds along the northern flank. It appears to be responsible also for the long, narrow limestone reëntrant one to two miles west of Siegersville.

South of the Stines anticline, the structural data in the county are meager, because of the narrowing down of the area occupied by sandy Martinsburg beds. There is probably a small anticline at Seiberlingsville, judging from the shale-into-sandstone reëntrant there, which may in turn tie in with the limestone-shale reëntrant southwest of Oreville. A well-defined syncline is represented in Huckleberry Ridge. This structure is thought to continue westward into Berks County in the sandstones southwest from New Smithville, but we are not able to comment with assurance on this item. It is bordered to the south by a reëntrant, the Cove, south of Haafsville, another anticline, which in turn is succeeded by a synclinal "finger" south of Laros.

THE LIMEPORT OUTLIER

In the southeastern corner of Lehigh County, there is a small, isolated area of phyllitic material that has been correlated with the Martinsburg. It is shown on Miller's Allentown Quadrangle map. The patch is slightly elongated in a north-south direction, is oval in outline, about half a mile long by a quarter of a mile wide. The thickness of the beds is unknown, but can hardly be more than 60 or 80 feet. The author found no fossils in them. The phyllite lies nine to ten miles southeast from the nearest known Martinsburg, the southern shale belt.

Northwest of the village of Limeport, exposures are good along the east side of the concrete highway. Here beneath the phyllite a succession of abandoned quarries exposes limestone which belongs to the Allentown (Cambrian) formation. The shale-limestone contact is sharp, may be a fault, but evidence of movement was not positively seen. The phyllite rests upon massive limestones (Plate 23) more or less brecciated, with black chert nodules present. The upper surface of the limestone where exposed is rough with small, ferruginous concretions. The contact has approximately the attitude: N.22°E.; 31°S. This is nearly parallel to the bedding of the phyllite, but the highly altered condition of that rock has all but obliterated any traces of stratification save for a few thin sandstone lenses. Lithologically, the phyllite is most like similar beds along the south border of the Martinsburg in Dauphin County. As no such beds are known from other Cambrian or Ordovician formations in eastern Pennsylvania, the most reasonable deduction is that this is an outlier of Martinsburg.

THE TACONIC DISTURBANCE

From comparatively early days in American geology, the Taconic Disturbance has interested geologists, but it is only in the last few decades that it has received more than a passing recognition in Pennsylvania. A pioneer in calling attention to evidence for its extent and intensity in eastern Pennsylvania is B. L. Miller. Recently Cleaves and Willard reviewed its effect. Their paper was neither complete nor final, but it attempted to show, as fully as was then known, what formations and areas were involved in the Taconic in Pennsylvania. In particular they stressed the significance of the disturbance as a correlative factor.

The Taconic Disturbance is dated pre-Richmond but post-Pulaski. It effected the entire Martinsburg. Since the disturbance was followed by an interval of quiescence and peneplanation prior to deposition of the overlying Bald Eagle and Juniata beds, it cannot have been later than middle Maysville. The Pulaski is dated as early Maysville. It has been demonstrated that any Ordovician sediments that might have followed the Shochary (Pulaski) sandstone in eastern Pennsylvania could have been red beds, but were not marine black shales. Is this not final evidence that the three-fold Martinsburg is impossible? If the northern shale belt were post-Pulaski, that is, later than early Maysville, it must also have been pre-middle Maysville to have been deposited before the Taconic Disturbance. Yet these beds were so consolidated as to have behaved as firm rock when they were subjected to Taconian compressive forces. Was there time for them to form and be consolidated in the interval mentioned? The events are tabulated in the following chart:

Summary of Events *

Chronology	Events
Medinan	Tuscarora-Shawangunk deposition in invading sea.
Richmond	Bald Eagle conglomerate and sandstone and Juniata red beds deposited to west and northwest as reworked, transported, residual soils derived from land to the east and southeast, chiefly continental facies.
Richmond-Maysville interval	Uplift by tilting, unaccompanied by folding, of the eastward landmass; rejuvenation of streams.
Late Maysville	Quiescence; accumulation of red regolith over peneplaned but exposed Martinsburg and older formations to the eastward.
Middle Maysville	Taconic orogeny, folding, uplift; followed finally by peneplanation growing progressively more deeply penetrating from the Susquehanna Valley eastward.
Early Maysville	Deposition of the Fairview and Shochary sandstones to the west and east respectively, perhaps in separate basins, possibly connected by subsequently eroded, similar beds. This marked the closing events of Martinsburg (or Reedsville) sedimentation and ended in the withdrawal of the sea.
Eden and older	Deposition of Upper Martinsburg and Reedsville shales.

* After Willard and Cleaves (1939, p. 1195).

THE JUNIATA AND BALD EAGLE

It is not necessary to dwell for long upon the remaining Ordovician sedimentary rocks in Pennsylvania and Lehigh County. The prime significance of the recognition of Bald Eagle conglomerate in Lehigh, Berks, and Northampton Counties is that it more closely dates the Taconic Disturbance in that section of the State. Dating the Taconic adds precision to our knowledge of the upper age limit of the Martinsburg.

BIBLIOGRAPHY

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Moseley, J. R., Notes on the structure and stratigraphy of the Martinsburg formation. 1938.
Ward, Freeman, The Martinsburg shale along the Delaware River. 1932.
———, The Martinsburg shale as seen in the Eckville-Lynnport-Kempton area, Pennsylvania. 1936.
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———, Martinsburg shale, Shartlesville-Straustown. 1939.

SILURIAN SYSTEM

By Benjamin L. Miller

TUSCARORA FORMATION

Distribution.—The Tuscarora formation of Kittatinny (Blue) Mountain on the northern boundary is the only representative of the Silurian in Lehigh County. The contact between the Martinsburg, which underlies it, and the Tuscarora can not be accurately located, as it is almost everywhere concealed beneath a cover of thick talus. In some places it is probably near the base of the mountain and in other places half way up the slope. The crest of the mountain, however, throughout the length of the county is comprised of the resistant rocks of this formation. Since the strata dip to the north, the major portion of the formation lies within the boundaries of the adjoining counties of Carbon and Schuylkill.

Lithologic characteristics.—The Tuscarora deposits are readily distinguishable from those of any of the other formations of the region. They are primarily coarse conglomerates composed of rounded quartz pebbles up to a few inches in diameter firmly cemented by siliceous matter. They are the hardest rocks of the county and the most resistant to erosion (Plates 12 and 13). This accounts for the mountain. The beds are mainly massive and joints are few so that huge blocks occur in the talus overlying the Martinsburg shales on the southern slopes of the mountain. Shale pebbles occur in certain beds. Interbedded with the conglomerates are beds of sandstone and thin layers of black slate.

In some of the sandstone beds at Lehigh Gap quartz is almost the sole mineral of both the sand grains and the cementing material. Analyses show that the composition is such that the rock might be desirable for ganister or in the manufacture of glass. A few years ago some investigations were made in the Lehigh Gap to determine whether stone of this quality might be quarried economically. The writer was consulted and advised the interested parties that desirable material was present but the interbedding of the high silica layers with others less pure would probably make the expense too great for economical utilization.

The Tuscarora strata are better exposed on the east side of the Lehigh River in Northampton County and therefore a carefully measured section by C. K. and F. M. Swartz (1931, pp. 643-644) is quoted:

	Thickness in feet
Tuscarora sandstone:	
Massive gray conglomeratic sandstone	52
Concealed in large part. Massive gray conglomeratic sandstone exposed at places	165
Massive gray sandstone with some thin bands of black shale; many beds of sandstone are conglomeratic with pebbles up to several inches in diameter; some black shale pebbles	237.5
Disintegrated conglomerate, stained yellow	2.5
Total thickness of Tuscarora formation	457
Martinsburg shale:	
Dark-gray shale and gray argillaceous sandstone	....

Paleontologic characteristics.—No fossils in the Tuscarora have been found in Lehigh County. At the Delaware Water Gap several species of eurypterids were found years ago. Also near Little Gap, Northampton County, a fucoid or worm trail, *Arthrophycus harlani,* has been found. The coarse character of most of the strata would seem to account for the absence of fossil remains. If fossils other than *Arthrophycus* ever are found the chances are that they will be in the thin shale laminæ that are interbedded with the sandstones and conglomerates.

Thickness.—Only the lower part of the formation is present within Lehigh County and it is scarcely possible to determine what part of the 457 feet of the entire thickness is present. Perhaps the maximum thickness in the county is no more than 150 feet.

Name and correlation.—The formation is named for Tuscarora Mountain which forms the boundary of Juniata and Perry Counties, Pennsylvania. These strata were termed the Oneida and Medina by the geologists of the Second Geological Survey of Pennsylvania. In recent years these rocks have been correlated with the Shawangunk of New York State and that name has been used. The formation continues into Northampton County and was mapped as Shawangunk in the Northampton County volume (Miller et al. 1939).

C. K. and F. M. Swartz (1931) traced these beds across Pennsylvania and have correlated all of the beds exposed in Lehigh County with the Tuscarora of central Pennsylvania.

Willard and Cleaves (1939) have suggested, on the basis of a difference in the lithologic characteristics, that the basal 2.5 (3 or 4) feet of the Swartz section quoted above represents the Bald Eagle conglomerate and should not be included in the Tuscarora. The writer recognizes differences, but is not inclined to regard them as of stratigraphic importance. It is common to find basal conglomerates much more dirty or impure than the inter and overlying beds, due to the mingling of sediments derived from the underlying beds. This is well shown in the basal conglomerates of the Hardyston formation. The darker color can be explained in this way. Further, the limonite stains, conspicuous in the basal portion, and the feebly cemented pebbles can be well explained by the free circulation of oxidizing ground water at the unconformable contact.

Stratigraphic relations.—There has been general agreement that the Tuscarora, or the Shawangunk farther east, rests unconformably upon the Martinsburg shales. At Lehigh Gap this unconformity can be seen in a cut along the Lehigh & New England Railroad where the Martinsburg shales dipping to the northwest are truncated by the basal beds of the Tuscarora inclined in the same direction but with about thirteen degrees less dip. The basal conglomerate here is iron-stained and disintegrated. Nowhere else has this contact been observed by the writer.

It is of interest to note that J. P. Lesley[1] argued strongly against the existence of an unconformity (nonconformity) between these two formations.

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[1] Pennsylvania Second Geol. Survey, D3, vol. 1, pp. 32-35, 1883.

Beyond the borders of the county the Tuscarora is conformably overlain by the Bloomsburg red shales.

Local details.—There are few localities within Lehigh County where the Tuscarora strata can be observed in place. The sides of Kittatinny (Blue) Mountain are covered with large and small blocks of the resistant sandstones and conglomerates so that almost any part of the mountain slope will show the different types of rocks of the formation. An occasional specimen of sandstone shows prominent ripple marks.

The most complete section is in Lehigh Gap. Excellent exposures are seen at the three places of particular scenic interest described and illustrated in an earlier portion of this volume. They are Bear Rocks, Bake Oven and Bake Oven Knob, and the Devil's Pulpit.

TRIASSIC SYSTEM

By Edgar T. Wherry

BRUNSWICK FORMATION

Distribution.—A strip of land about two miles in width along the southeastern boundary of Lehigh County is underlain by rocks of the Newark group, so named because of the excellent exposures in the vicinity of Newark, New Jersey. This group is divisible into three formations, known from typical occurrences in New Jersey as the Stockton, Lockatong, and Brunswick; only the last is present in Lehigh County. These formations reach their maximum development in Bucks County, which adjoins Lehigh on the southeast. They extend from there northeastward to the Hudson River, and southwestward into Chester County, Pennsylvania.

Lithologic characteristics.—The rocks of the Newark group were deposited in a long narrow trough extending in a general southwest to northeast direction from North Carolina to Nova Scotia. This trough was bounded on both sides by high mountain ranges formed during the Permian or Appalachian revolution. Moisture-laden winds being largely intercepted by these mountains, the climate in the trough was arid; and although vast quantities of water must have been poured into it by descending streams, evaporation removed this so rapidly that no extensive, continuous, deep body of water seems ever to have occupied the trough. Locally gaps developed in the eastern mountain barrier of sufficient depth to permit outflow of water to the sea, but there is no evidence that salt water ever flowed into the trough in appreciable quantity. The Newark beds are thus essentially of continental, and non-marine, origin.

In the mountains bordering the Newark trough the climate was apparently warm and mild over considerable areas, favoring the development of red soils, owing their color to colloidal hematite, that is, completely oxidized and essentially anhydrous ferric oxide. Large quantities of clay, colored pink by such material, were carried by erosion into the streams, and transported to the bottom of the trough; and although the Newark sediments vary in color, deep pink or red hues are predominant over vast areas, and through great thicknesses of the deposits. Pink clay coats the surfaces and penetrates crevices of all the coarser fragments; it serves as the cement which has consolidated the originally incoherent sediments into fairly hard rocks. Locally, where the supply of pink clay was deficient, the Newark beds may be gray; and they have also turned gray in places where heated waters given out by intruding igneous rock-magmas have changed the red mineral, hematite, into the black iron oxide, magnetite. Elsewhere carbon compounds liberated by the decay of vegetation have reduced the iron to the ferrous state, resulting in a greenish coloration; or the accumulation of excess carbon has blackened the beds. But, however prominent one or another of these colorings may be at individual localities, one can not go far in any direction before encountering the deep red rocks characterizing the Newark group in general.

Even where no actual outcrop exists, the nature of the underlying material can often be recognized by the color of the soil resulting from present-day weathering of the substratum. The coloring effect of hematite is so powerful that many Newark soils, known to soil surveyors as Penn soils, are nearly as red as the rocks themselves. On the other hand, the gray or otherwise-colored rocks of this group give rise to yellowish or brownish soil types.

The streams descending from the mountains into the Newark trough were evidently highly variable and intermittent, so that the materials they carried down and deposited changed markedly from time to time. Streams so sluggish as to be capable of transporting only the finest mud would now and again receive so much more water that they could bring down sand, gravel, and even good-sized boulders. These would form coarse strata superposed on the fine ones and would in turn be covered by finer deposits when the water flow slackened again. When hardened into rock, the result was a series of formations termed shale, sandstone, and conglomerate, varying greatly in thickness from place to place, and following one another in various sequences. Near the margins of the trough, where streams emerged from the mountains, coarse materials would naturally be deposited in the greater amounts, and finer and finer sediments would be carried progressively further out toward the center of the trough. In Lehigh County the bulk of the Newark rocks represent marginal deposits, and are correspondingly relatively coarse-grained, consisting indeed largely of the aggregate of pebbles and boulders known as conglomerate, with only subordinate and local beds of the finer-grained sandstone, and the still finer argillite or shale.

The conglomerate consists of stones of all sizes up to at least 2 feet in diameter, embedded in a red clayey matrix. In some places the stones are chiefly sandstone, and elsewhere chiefly limestone; occasionally these two rock types are uniformly mixed. Fragments of shale, slate, gneiss, and other rocks are occasionally present, but rarely if ever dominant. The sandstone fragments are almost always well-rounded, indicating transportation from a considerable distance; their lithology resembles closely that of the Shawangunk (Tuscarora) formation of Kittatinny (Blue) Mountain, and they may well have been broken from beds of that formation exposed in Triassic times. The limestone fragments, on the other hand, are mostly angular or subangular, proving that they came from close to the margin of the trough. In lithology and particularly in rather low magnesium content they resemble limestones of Devonian age now exposed only far to the north of Lehigh County; but it is quite possible that during Triassic times there were outcrops of these limestones closer to the margin of the Newark trough, from which the fragments could have been broken.

Locally the conglomerate is so resistant to weathering that it stands out in prominent ledges or small cliffs on hills and along streams. The limestone pebbles tend to dissolve out, however, giving such outcrops a peculiar porous structure. More profound weathering disintegrates the matrix as well, liberating the resistant sandstone boulders, which then accumulate in the soils or are carried down stream valleys and spread out at lower levels.

These conglomerates probably represent fossil alluvial fans, and so merit the designation "fanglomerate." They were presumably deposited where canyons had formed in the marginal mountains, and torrential streams developed, carrying along the debris resulting from erosion at higher levels, and depositing it where their flow was checked, as they entered the bodies of water in the bottom of the trough. The sandstone boulders are in part of such large size that it seems unlikely that they could have been brought all the way from outcrops many miles away by water alone, and they may have been rafted part way by cakes of ice which no doubt formed at the high elevations to which the mountains of those days reached. It is interesting to note that several large bodies of conglomerate occur in the Newark at points athwart the courses of present-day streams, suggesting that the same geological features that have led these streams to take up the exact course they now follow were operative in Triassic times.

When the Triassic period came to a close all deposition ceased, and the sediments gradually hardened into the present rock masses. The region was then subjected to earth movements, and the strata, originally horizontal or essentially so, became folded into a series of anticlines and synclines, the axes of which have a northwest-southeast direction, that is, lie perpendicular to the long axis of the trough. An anticlinal axis lies near Hosensack, a synclinal one some 3 miles further east, and a gentler anticline toward the southeast corner of the county. The strata dip away from the anticlinal axes in both directions with angles ranging in this area from 10° to 30°.

Thickness.—Sections measured to the south of the present area in Bucks and Montgomery Counties indicate the Brunswick formation as a whole to be around 12,000 feet thick. Only a portion of this total is exposed in Lehigh County. On the assumption that the beds are all monoclinal, and that faults parallel to the strike could repeat them without being detected, some geologists have urged that such values for the thickness of Newark beds are excessive. Actually, however, the beds are folded into anticlines and synclines to such an extent that faults could not repeat beds without their presence being obvious.

Name and correlation.—In earlier geological survey reports the rocks under consideration were termed the Mesozoic or New Red sandstones. After the publication of a detailed study of these rocks by

H. B. Kümmel, then State Geologist of New Jersey, in 1896 the term Newark group became generally adopted by geologists. The uppermost beds included in the group were termed Pottstown shales in reports of the Second Geological Survey of Pennsylvania, but the work done on them in New Jersey was so much more detailed and thorough that the name Brunswick proposed in that State has come to be used in Pennsylvania as well.

There is only a single record of fossils in these rocks in Lehigh County. In a road cut southwest of Hosensack, reptile bones were found, and were duly named by Isaac Lea in 1854 *Clepysaurus pennsylvanicus*. Further south, and chiefly in beds below the Brunswick, both plant and animal remains have been collected at various points. All are of Triassic age, but exact correlation with European subdivisions of this period is scarcely practicable.

Stratigraphic relations.—In the southeastern part of the Newark area the Brunswick conformably overlies the Lockatong, and it in turn the Stockton, the last resting unconformably on pre-Newark rocks. In Lehigh County, however, the lower Newark formations are not exposed, and interest centers on the relations between the Brunswick beds and the pre-Newark rocks that adjoin them on the northwest.

No actual exposures of the contact between marginal Newark strata and the underlying Paleozoic or pre-Cambrian rocks are known in Lehigh County, and there has been a tendency on the part of some workers to consider the boundary as conditioned by an interlacing system of normal faults. The existence of these faults is purely speculative, however, and it is simpler to interpret the observed distribution of the formations as due to deposition of the Newark strata in a body of water encroaching northwestward over a land surface which had long been subject to erosion, and had been carved into a series of low undulating hills with broad valleys between. For example, three-quarters of a mile east of Hosensack there are two abandoned quarries in Cambrian limestone; on the hill south of these quarries Newark conglomerate swings around above the limestone. Then eastward, beyond a depression where no rocks are visible, this conglomerate descends to a lower level and crops out for hundreds of feet along the south bank of Hosensack Creek. A normal fault could not account for such a contact, whereas deposition on an irregular floor, with subsequent removal of portions of the strata, would explain it adequately.

Again, one mile southeast of Limeport the boundary between the Newark and the underlying formations shifts from a northward to a northeastward course. At the point where the direction changes, a streamlet has cut a small valley through the conglomerate, revealing a body of disintegrated pre-Cambrian gneiss overlain by a few feet of Hardyston quartzite. One would have to postulate a complex system of normal faults to account for this, whereas it can be simply explained as a case of erosion revealing the basement on which the Newark beds were laid down.

It is altogether probable that the Newark strata formerly extended considerably farther north than the present marginal outcrops. In Lehigh County there is no evidence for this other than the occasional finding of pink-stained pebbles, which appear to be residual from weathering of the Newark conglomerate, a mile or two northwest of the northwesternmost solid outcrop. However, in Berks County, nearly thirty miles northwest of the present continuous mass of Newark rocks, there exists an erosion remnant of typical Brunswick conglomerate superposed on Ordovician shale at the summit of Hexenkopf Hill.

IGNEOUS ROCKS

Toward the close of the Triassic period molten magmas of basaltic composition arose from a deep-seated source and invaded the sediments. They solidified in part in more or less vertical fissures, forming long narrow dikes; they also cut across the beds to form irregular masses of various shapes; and they even flowed horizontally between strata, solidifying in great sheets known as sills. In Lehigh County there are three occurrences of these igneous rocks: a series of dikes south of Hosensack; a hook-shaped, cross-cutting mass farther northeast; and a large sill, the northern tip of which barely enters the county east of Coopersburg.

Cooling slowly at considerable depths below the surface, these magmas formed the rock known as diabase, colloquially termed trap rock, or again black granite. This is made up of interlacing laths of plagioclase feldspar, showing under the microscope extensive twinning, and optical properties indicating it to be a labradorite. In the interstices between the feldspars there is a large amount of augite, and minor amounts of biotite, magnetite, and rarely a few other minerals. Throughout the smaller masses, and at the margins of the larger ones, the texture is fine-grained, and the crystals are scarcely visible to the naked eye; but in the interior of the larger diabase masses the grains are so coarse as to be readily visible.

The fresh diabase as exposed in cuts and quarries is a hard, tough rock of greenish-black color. It is usually traversed, however, by numerous joints which break up the solid mass into angular blocks. In the course of time rain water penetrates along the joint cracks, and gradually decomposes the surface minerals. Such decomposition takes place most rapidly at points where the cracks intersect, and when erosion finally brings the blocks to the earth's surface, they are bounded by curved surfaces, and are then known as boulders, niggerheads, or iron-stones. The iron set free from the augite turns into colloidal ferric hydroxide, which coats the surfaces of the boulders with a bright rust-yellow crust. These boulders accumulate in the soil above the diabase masses, and their presence may be used to map the positions of these, even in the absence of any solid outcrops.

Cooling of the diabase magmas was accompanied by the giving out of considerable amounts of heated solutions, which penetrated the sediments to distances of hundreds or locally thousands of feet, producing metamorphic changes. These included the transformation of soft red shales into hard gray hornstone, the color-change resulting from the original red hematite becoming the black mineral, magnetite. Various secondary minerals were also formed, and their crystallization in pre-existing spaces between the grains resulted in the hardening often observed. Where the original sediments were calcareous these changes were especially striking, although in Lehigh County no extensive formation of metamorphic calcium-bearing silicates seems to have occurred. Along the highway a mile southeast of Hosensack there are good exposures of calcareous conglomerates showing various degrees of metamorphism produced by nearby diabase dikes.

QUATERNARY SYSTEM

By Benjamin L. Miller

The Pleistocene geology of Lehigh County consists of the glacial, alluvial, colluvial and residual deposits. Of these the glacial is of so much greater importance and general interest that it overshadows all the others.

Glacial Deposits

Long before the acceptance of the idea of an invasion of the northeastern part of the United States by an ice sheet, geologists had noted and described the cobbles and boulders that are a common feature of extensive areas. In some instances it was noted that they were lithologically similar to rocks in place at varying distances to the north and northeast. The only explanation proposed was that they had been brought to their present locations by extensive flood waters coming from the north. In the Lehigh Valley they were attributed to great floods that occurred when the waters of a supposedly large lake lying to the north of Kittatinny (Blue) Mountain, and impounded by the mountain as a dam, burst the barriers at the Delaware Water Gap and Lehigh Gap and flooded the areas to the south. These torrents of water were believed to have carried and distributed gravels and boulders over almost all parts of the county.

Even before 1850 when Louis Agassiz advanced the idea of a former ice sheet, several other investigators had suggested that the large boulders must have been carried by floating ice cakes or icebergs. Agassiz' hypothesis did not meet with ready acceptance generally although J. P. Lesley states[1] that in 1850-1851 he and Prof. Edward Desor of Switzerland did recognize scratches (striæ) on some rocks near Ashland as produced by ice.

Soon after the establishment of the Second Geological Survey of Pennsylvania in 1874 attention was directed to the glacial deposits of this region. Since then many geologists have contributed to the discussion and added valuable data. It does not seem advisable to describe or even list each publication inasmuch as they are included in the Bibliography which forms an earlier chapter in this volume. Attention may be directed to the articles by C. E. Hall (1876), F. Prime, Jr. (1879), J. P. Lesley (1881), G. Frederick Wright (1882, 1889 and 1893), H. C. Lewis (1883, 1884 and 1885), T. C. Chamberlain (1890), Angelo Heilprin (1890), R. D. Salisbury (1892 and 1902), J. Barrell (1893), E. H. Williams, Jr. (1893, 1894, 1898, 1917 and 1920), F. Ward (1929, 1934 and 1938), and F. Leverett (1934). Among these H. Carvill Lewis and E. H. Williams, Jr. deserve special mention. Prof. Williams spent more time and accumulated far more detailed information than any of the other investigators. For years he and groups of his students tramped the region on foot over week ends, holidays and vacations, collecting every bit of information possible. Among these students was Joseph Barrell who later won recognition as one of the ablest and most careful geologists whom this country has produced and whose early death was a distinct loss to American geology. Unfortunately, Prof. Williams' contributions were not written in the best form to convey his ideas to the reader. The writer feels that had he not had the opportunity to go into the field with Prof. Williams on numerous occasions he might never have fully comprehended his points of view. The destruction of all his detailed field notes by fire was a great loss. The writer here wishes to record his sincere appreciation of Prof. Williams and his work.

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[1] Pennsylvania Second Geol. Survey, vol. Z, p. XLI.

The writer does not regard himself as a glacial geologist and therefore feels his limitations in preparing this discussion. However, it may prove useful to later investigators to have a summarized description by a person familiar with the region and with many phases of the problem. Having taken a number of glacial geologists to critical places in this region, opportunity has been afforded to learn the different interpretations that have been offered by them. This applies particularly to geologists who have never published their ideas on this region.

One of the most important questions to be considered concerns the number of times the glacial ice advanced into the region. Did the ice push downward one, two or three times from the northeast and come within the present limits of Lehigh County? Also, how shall the deposits of this region be correlated with those of the Mississippi Valley, the generally accepted type sections?

The earliest workers in the region recognized only one ice invasion, the one best preserved and most noticeable because of the development of the fine terminal moraine in the Bangor region of Northampton County. This has been correlated with the Wisconsin ice sheet of the Mississippi Valley.

When glaciated cobbles were discovered to the southwest of this morainal belt, they were explained as outwash material carried by the water resulting from the melting of the ice. However, when ice-deposited material, glacial till, was found in these places it was recognized that at some time glacial ice did extend beyond the "terminal moraine." The belt was termed the "glacial fringe," the "attenuated border" or "extra-morainic drift." Prof. Williams searched the Lehigh Valley to determine the extent of this "fringe." He found it to extend as far as the Schuylkill River, near Shoemakersville, Berks County. To this fringe he applied the name Kansan, but used the term in a different sense than do the geologists in the Central States. He believed that the Kansas deposits, as he described them, represented the first advance of the ice sheet in the region and that near its margin it was thin and accomplished little glacial erosion. He also believed that the ice was more fluid near the margin because of the melted ice and that the front receded quickly. When the front had moved back to the Bangor region there was a long halt and the pronounced terminal moraine was built. Williams therefore believed there was but one ice sheet in the region and his "Kansan" designation only meant the farthest and most rapid advance and retreat of the Wisconsin. In places he terms it the First Phase. When he was confronted with the evidence of greater age characteristics of the deposits beyond the "terminal moraine" he replied that it was natural to find these old-age features because the first advance of the ice picked up the weathered material on the surface. He maintained that the finding of a single or a few fresh rock fragments in the "fringe" deposits, materials that seemed as fresh as similar pebbles in the Wisconsin glacial deposits, was sufficient evidence of approximately the same age of the two. He expressed his view in the expression "the time elapsed since drift deposition is measured by the freshest part." In his search he found pebbles which he regarded as fresh as those of the Delaware Water Gap region. He also called attention to the fresh appearance of the slate directly beneath the till of the "attenuated border" in different places, particularly in one quarry near Northampton (Siegfried), Northampton County.

In general Prof. Williams' idea of a single ice invasion has not been accepted, although George H. Ashley has recently expressed an interest in this view. The most commonly accepted interpretation is that the glacial deposits of the Bethlehem region belong to a much earlier ice sheet than the Wisconsin. For some time they were referred to the Jerseyan, an older series of deposits described in New Jersey.

When Frank Leverett came into the district and saw the moraines in the Saucon Valley and near Trexlertown in Lehigh County, he concluded that there were two distinct ice invasions before the Wisconsin. He particularly investigated the deposits in the vicinity of Bethlehem and Allentown (pl. 33) and decided that they and the moraines mentioned belong to an ice sheet that he termined the Illinoian because of resemblance to the Illinoian of the Mississippi Valley.

The farthest advance of the ice south of the Illinoian moraines for the present is designated as the Jerseyan, which is roughly correlated with the Nebraskan of the Central States.

So far, no occurrences have been found in the Lehigh Valley where deposits of two of these sheets are in contact. That also applies to any interglacial beds such as have been described in Iowa and other Central States.

Accepting the belief in three different ice invasions in the Lehigh Valley, the evidence for each one will be discussed.

WISCONSIN ICE SHEET

Although geological formations are generally described in order of age, the oldest first, it seems better to reverse that order in the discussion of the successive ice invasions. The marks of the Wisconsin ice sheet are well preserved and in many aspects readily decipherable, whereas those of the earlier sheets are scanty and vague in most places and can best be interpreted after a study of the most recent one.

The Wisconsin ice sheet did not advance to the borders of Lehigh County. In the Lehigh Valley it extended only a short distance west of Bangor, Northampton County. However, some effects of this invasion are seen in Lehigh County in the great amount of sand and boulders that came down the Lehigh River when some of the Wisconsin ice covered the headwaters of the river. Many huge boulders encased in ice floated down the greatly enlarged stream and were dropped along the stream but at much higher levels than the present river.

ILLINOIAN ICE SHEET

In a recent publication[2] of this Survey, Leverett has given (pp. 1-11) a comprehensive summary of the work done by previous investigators of the "extra-morainic drift" and has also described the Illinoian drift as it is developed in Northampton and Lehigh Counties. He describes and maps the Illinoian terminal moraine in Saucon Valley and that part of Bethlehem lying between the slate region and South Mountain. The following excerpts from Leverett's report (pp. 63-72) deal with Lehigh County:

> The Illinoian drift south of Blue (Kittatinny) Mountain in Pennsylvania covers nearly the entire area of the limestone and slate formations between Blue Mountain and South Mountain from the Delaware Valley westward to a line a few miles beyond the southward-flowing part of Lehigh River. . . . Near Bethlehem, it extends several miles south of Lehigh River into a lowland drained by Saucon Creek, but elsewhere, from Easton up to Allentown, its border is very near the river. The border turns away from South Mountain at Emmaus and runs northwestward past East Texas to Chapman. It then runs northward past Siegersville about to Schnecksville. There is some uncertainty as to its further course, for the surface here is more hilly, and the deposits more scanty than in the lower country to the south. Some hills rise above 900 feet, and seem to be free from erratics. The depressions among them carry very little till, but contain many stones, a few of which are glaciated. Some of the stones seem to have been rounded by water action, though many of the sandstones may have been rounded by exfoliation. These stones are present in notable amount as far out as a line running from Schnecksville past Pleasant Corner about to New Tripoli. Williams reported that some of the stones in this region were brought over Blue Mountain, and stated that the county bridge over Jordan Creek near Pleasant Corner has in its foundation stones of such derivation.[3] There is a strip of somewhat lower land between these hills and Blue Mountain, running westward from Slatington, that carries deposits of till which have the general aspect of the Illinoian till. The westernmost of these deposits noted by the present writer are exposed in railroad cuts between Germansville and New Tripoli, on or near the divide between Jordan Creek and Maiden Creek, which is the divide between the Lehigh and Schuylkill drainage basins. Till deposits are conspicuous from the headwaters of Jordan Creek eastward past Slatedale and in slate pits around Slatington. They lie mainly between the Reading Railroad and Blue Mountain, being scanty south of the railroad, and are restricted to a level but little more than 700 feet above sea level. The altitude is about 700 feet in the railroad exposures near the Lehigh-Schuylkill divide. If the ice covered ground at 700 feet that far west it may have covered the hills south of Slatington that reach 900 feet. It seems probable that the district east of Lehigh River was entirely covered up to the base of Blue Mountain. The height to which the ice rose on the slope of this mountain has not been determined. It seems to have reached a markedly higher altitude on the north border of the lobe, next to Blue Mountain, than on the south border, next to South Mountain.

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[2] Leverett, Frank, Glacial deposits outside the Wisconsin moraine in Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 7, 1934.

[3] Geol. Soc. America Bull., vol. 5, p. 292, 1894.

Topography of the Drift

A distinct moraine is found along the border of the Illinoian drift where it terminates on the limestone lowland west of Allentown. . . . In its passage across the limestone lowland from Emmaus to Chapman the moraine has a width of half a mile to a mile and a relief of 20 to 40 feet above the district outside, which probably represents about the thickness of drift along the moraine. The topography is of a subdued swell and sag type, as if the swells had suffered considerable toning down as a result of relatively long exposure to surface wash. The sags and basins also are not so sharply outlined as in the moraines of Wisconsin drift.

Thickness of the Drift

Except in the morainic part near the outer border, and where it fills valleys, the drift is generally a very thin sheet, scarcely forming a complete cover over the rock formations. It is generally too thin to conceal the basins that had been developed by underground drainage in the limestone prior to this glaciation, and they remain as saucer-like depressions from 3 to 10 feet in depth. In the slate areas depressions have been filled with till to a depth of 30 feet or more, as revealed in the quarrying of the slate. These depressions occupy only a small percentage of the slate area, scarcely as much as that occupied by the basins in the limestone. On the higher parts of the slate area the drift is very thin and patchy.

The greatest thickness of drift of which a record has been obtained was found in a well put down in the west part of Bethlehem by E. H. Williams, Jr. This well penetrated 137 feet of drift, and reached rock at a level 40 feet below the adjacent part of Lehigh River. This record is of interest in showing that the valley erosion had reached its lowest level there before the Illinoian stage of glaciation.

Character of the Drift

The Illinoian drift of this district consists mainly of a reddish clayey till. In places it carries sufficient gravel to warrant opening pits in it for commercial use. The clayey part of the till may have been derived largely from the residuary clay left from the solution of the limestone, but most of the stones in the till have come from other formations over which the ice sheet had passed before it invaded the limestone area. On the southern border of the limestone area the drift carries gneiss and other rocks derived from South Mountain.

Williams has given the following description of the till, and interpretation of its derivation.[4] The description appears to apply to a section near Bethlehem.

> It shows a surface clay, unstratified, and carrying rolled stones from the Blue Ridge (Blue Mountain), and beyond (Oneida, Medina, Oriskany, Helderberg, Marcellus, Hamilton, etc.) and covering a till that varies widely in its nature, but is mainly of local stuff, of angular shape, mixed with a greater or less proportion of rolled material similar to that in the clay, and locally with angular masses of the same. This latter rests uniformly on glaciated rock in place. This section may vary by the omission of the till, or by the introduction of local stratified deposits of sand and clay.

Williams appears to have held the view that the residuary clay of the limestone was almost completely gathered up and reworked to form the till, for he found outcrops of the limestone within the glaciated district to be generally fresh rock. He also noted a general similarity of material from top to bottom, described as follows:[5]

> First, the admixture of fresh and oxidized materials at all levels, and the uniformity of oxidation at any point along a vertical section * * *. This curious and persistent admixture proves that oxidation preceded

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[4] Williams, E. H., Jr., Am. Jour. Sci., 3d ser., vol. 47, p. 34, 1894.

[5] Idem. p. 35.

> glaciation. In the slate belt the proportion of decomposed slates increases from north to south, and the same is true of limestone in the limestone belt, only chert being found at the south.

In another paper[6] Williams interpreted the surface clay to be a deposit in ponded water, held in front of the receding ice border, to a level corresponding to the lowest pass on the Lehigh-Schuylkill divide, about 500 feet above sea level. He named the hypothetical body of water "Lake Packer" and called the surface clay "Packer clay." The question of the occurrence of such ponding is taken up on a later page.

Williams made the suggestion[7] that drumlins may be present near Bingen, Siegfried, and Northampton, his statement being as follows:

> It has not been fully determined whether the ridges of unstratified gravel at Bingen, Siegfried, Northampton, etc. are drumlins or portions of lateral or terminal moraines. The two latter deposits are on the north bank of the Lehigh, and are 10 to 20 feet thick, from half a mile long, and from a few hundred feet to a half mile wide. The chances are in favor of their being drumlins, and connected with the subglacial drainage of the region.

The present writer could find no drift hills in the vicinity of these places that have the form of drumlins. Furthermore, drumlins are not a product of subglacial drainage.

Several of the deepest exposures of drift in the Illinoian area south of Blue Mountain were examined by the writer and found to exhibit a wide difference in the character of material, as may be seen by the following notes.

In a slate pit in the west part of Slatington there is an exceptional exhibit of drift. The lower 10 to 12 feet is a stony, partially assorted material, probably water-bedded. Above this is about 40 feet of clayey till. This is gray in part of the north wall of the pit to a level within 10 feet of the top, above which it is reddish, but changing to brown near the surface. On the south side of the pit there is 15 to 20 feet of reddish till directly above the assorted material. The color changes upward to brown at about 6 feet from the top. This is the only pit in the Illinoian drift in this region in which gray till has been noted, and the cause of the color has not been determined. It may be due to the incorporation of residuary clay from gray slate. The till of this region is usually brown or reddish from top to bottom even where it is 30 to 40 feet thick. As suggested by Williams, it appears to have been oxidized before it was gathered up and redeposited by the Illionian ice sheet.

Rauch's pit in Bethlehem, described repeatedly by Williams in his early papers, includes gravel and sand deposits underlying a surface clay, and overlying a sheet of till. The gravel and sand deposits show a cross-bedding with dip to the south, in the direction of drainage from the ice border. This gravel was not well exposed in 1927, at the time of the present writer's visit. It outcrops in the west bluff of Monocacy Creek, a northern tributary of Lehigh River, and at a level about midway of the slope. It is thought by Williams to be restricted to the west side of the valley. The clay cover becomes thicker in passing west from the border of the valley, as shown by the depth penetrated in cesspools to reach the gravel.

A large gravel pit (pl. 39, A) north of the Bethlehem-Allentown electric car line in the east part of Allentown is excavated to a depth of 25 feet. Over the gravel is a thin cover of bouldery clay 2 to 5 feet thick, with stones as much as 3 feet in diameter. In the east part of the pit a thin sand bed underlies the bouldery clay. Between the beds of gravel there are also sandy beds several inches thick at various levels in the walls of the pit. The bedding is horizontal and shows no evidence of disturbance by an overriding ice sheet, a feature taken by Williams to indicate that the bouldery clay was laid down in ponded water outside the ice border, and not directly by the ice sheet. The gravel has a gray aspect, but this seems to be due to the large proportion of light colored rocks in it, rather than to lack of oxidation.

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[6] Williams, E. H., Jr., Geol. Soc. America Bull., vol. 5, pp. 286-289, 1894.

[7] Idem. p. 289.

There are extensive clay pits at brick yards in the south part of Allentown. Boulders are conspicuous in the upper 6 feet of the deposit. The state of oxidation is more pronounced in this part than in the less stony underlying till that is drawn upon for brick material. The till is brown as far down as the excavations extend, about 20 feet.

Extensive clay pits have been dug for brick manufacture in the north part of Emmaus, on the crest of the moraine that forms the border of the Illinoian drift, but they had been abandoned in 1927, and exposures were not good. The clay seems to carry a large number of boulders, and the surface is undulating with characteristic morainic topography.

There are cuts 6 to 8 feet deep in the till on the highway west of Wescosville on the slope of the moraine which show the knolls there to be composed of bouldery clayey till. Similar material occurs in knolls cut through by the railroad at Chapman.

In a pit at the east edge of Siegersville the drift ranges from 5 feet to 25 feet in depth within the space of a few rods, owing to the unevenness of the underlying rock. It is a rather stony till with many waterworn cobblestones imbedded in a matrix of sandy clay.

Was There a Lake Packer?

Williams has interpreted the upper or surface part of the Illinoian drift in the limestone lowland, and within the Lehigh drainage basin, to be a lake deposit, and he has given the name "Lake Packer" to the body of water which he thought occupied the lowland. He inferred that ponding occurred before the ice sheet had reached its culmination, and that it recurred as the ice border melted back across the lowland.[8] He based the presence of such a body of water in some degree on hypothetical grounds, and gave it the altitude of the lowest part of the divide between the Lehigh and Schuylkill drainage basins in the limestone lowland, about 500 feet above sea level. But he also cited places where clay deposits rest on undisturbed gravel, and drew the inference that the clay was not deposited by the ice sheet for if it had been the gravel beds under it would show disturbance. Any lake deposits made during the advance of the ice were covered by glacial material to the extent that the ponded area was invaded and occupied by the ice sheet. The deposits as now exposed are thus restricted by him mainly to material laid down during the retreat of the ice border. This material termed "Packer clay" is described as follows in the paper above cited. From this description it will be seen that the "Packer clay" is of complex and varied character, much like till, and with little resemblance to the ordinary lake deposit.

> The clay is generally a reddish-brown, unstratified, sandy deposit, with a burden of glaciated, angular, and river-rolled material scattered irregularly through it. Very few striated stones have been found in the sections studied, and the bulk of the burden consists of river cobbles and pebbles, with a considerable proportion of perfectly angular fragments, derived from the rocks to the north of the locality where they occur in the clay. In the case of syenitic fragments, they occur near the South Mountain, where they could have been picked up by shore ice and carried a short distance. The greater proportion of the burden, however, are sandstones and chert, with a small amount of limestone and slate. The specimen of striated rock exhibited is from the clay, and shows the general freshness of the burden. The slates are generally fresh within, if oxidized externally, and workable slate can be found 10 feet from the surface, whereas the average depth of decomposed soil over an unglaciated area, or one exposed to long atmospheric action, is from 60 to 75 feet.

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[8] Williams, E. H., Jr., Geol. Soc. America Bull., vol. 5, pp. 286-289, 1894.

> The clay deposit varies from a perfectly clean clay to clayey sand as we go from the deep water of the south to the northern shallows. It is generally unstratified, but shows local areas of stratification. Its thickness varies from a few inches to twelve feet at West Bethlehem, but the general average is three feet.

. . . Concerning the state of oxidation of the clay (and this seems to include the till) Williams remarked:

> The high state of oxidation of the clay has been adduced as evidence of its great age, but the argument is worthless in view of the manner in which it was accumulated and the condition of the burden it carries. These glaciated, rolled and angular stones are generally fresh and unoxidized, as just described. We have therefore, a highly oxidized clay throughout, bearing at all levels fresh material. The mixture is no older than the fresh part, and the oxidation of the clay is either pre-glacial, from its having been part of the soil of the region (as gneiss, limestone, and slate all rot to such a clay), or due to oxidation while it was being deposited. Judging from the state of certain portions of the till, the chances are in favor of the former supposition. These fresh fragments antedate the great moraine and show that it also is of recent date. It may be argued that the clay (Packer) is the ordinary boulder clay of subglacial origin. If it were its deposition would have disturbed the stratification of the underlying gravels and sands, and there would not be the great proportion of angular fragments in the burden, nor, further, would we in hundreds of cases find the till shading gradually and conformably into the overlying clay.

. . . The present writer is accordingly very doubtful if ponding such as Williams postulated really took place. An examination of the district between the Lehigh-Schuylkill divide and the terminal moraine of the Illinoian drift did not bring to light any deposit that seems attributable to ponding. Furthermore the bouldery clay on the surface of the Illinoian drift appears to be better interpreted as a direct deposit from the ice sheet than as a deposit in ponded water outside the ice border.

As to the disposal of water from the melting of the Illinoian ice lobe, two dissimilar modes of discharge have been considered. One is the escape of the water along the south edge of the ice sheet at the base of South Mountain between Bethlehem and the Delaware Valley. This may have been to a considerable degree submarginal rather than outside the ice edge. . . . The other mode of escape is by underground drainage through the limestone of the outlying district west of the moraine. Much of the present drainage goes through underground channels. Water from a moderate rate of melting of the ice may have been thus disposed of without causing ponding outside the ice border.

Some additional notes are offered to supplement Leverett's descriptions.

As one drives across the limestone valley of eastern Lehigh County in certain places he observes quantities of boulders collected from the fields and piled along the fences. In places these piles are very conspicuous but along the fences in other places there are very few. At one time the writer and his students attempted to differentiate between those places thickly covered with glacial debris and the sections where the glacial deposits are apparently practically absent. This plan was abandoned when it was found that careful search revealed their presence on all the uplands. On the slopes there is seldom any evidence of glacial material. In the slate area where the hillsides are steep and the divides narrow there are many areas where the deposits seem to have been completely removed by post-glacial erosion.

The thickest deposits seem to have accumulated in depressions in the preglacial surface.

The size of the boulders varies greatly. In the Saucon Valley there are numerous sub-angular Tuscarora and Devonian boulders six to eight feet in diameter. Boulders with typical Oriskany fossils, especially *Spirifer arenosus,* are fairly common. The larger boulders generally bear abundant glacial striæ and the cobbles and pebbles rarely do. The abundance of well-rounded stream-worn cobbles suggests that the ice sheet as it crossed the Delaware River valley must have picked up enormous quantities of alluvial material which it spread over the Lehigh Valley. Much black flint is present in the local Illinoian glacial deposits. This probably was derived from the Tomstown, Allentown and Beekmantown formations and was present in the surface limestone residual clay before the advent of the ice.

One of the most interesting glacial deposits in Lehigh County is a small kame just north of Emmaus Junction. Topographically it is a low ridge extending almost at right angles from the trend of South Mountain in a northwest direction. When it was worked for foundry sand years ago the following section was exposed:

Section at gravel and sand pit 1¼ miles northeast of Emmaus

	Feet
Clay and fine gravel, not assorted	12
Stratified fine yellowish-brown sand which locally contains lenses of fine gravel	4
Very fine yellowish-brown sand containing some thin lenses of ocherous clay; exposed	17

The writer has never found any of the glacial till of the region that contains sufficient calcareous matter to produce visible effervescence with dilute acid. This test must not be applied in the vicinity of the cement mills without digging some distance below the surface, for there every exposed rock or bit of surface clay may have a film of pulverized cement rock on it. In places years ago when the mills threw much dust into the atmosphere even the bark of trees a few miles away would show this effervescence. No fresh limestone fragments have been observed. Instead all noted have had practically all the calcareous matter dissolved and the residual product readily crumbles into fine sand.

The entire subject of the Illinoian ice sheet in this region should receive more careful investigation by geologists familiar with glacial problems over a much larger region than the Lehigh Valley, as there remain numerous unanswered problems.

PRE-ILLINOIAN (JERSEYAN) ICE SHEET

Glacial deposits extend beyond the Illinoian terminal moraine mapped by Leverett. Boulders and cobbles occur in the surface soils in many places. A deposit worked for brick clay near Shoemakersville, Berks County, appears to be glacial till. It therefore seems that a still earlier ice sheet crossed Northampton and Lehigh Counties, but no deposits within either county can be definitely designated as belonging to such an ice sheet.

The only occurrences known to the writer that best lend themselves to this assignment are the gravels and cobbles that have been found on the tops of some of the gneiss hills in Saucon and Williams townships, Northampton County, and on a bench of South Mountain about a mile southwest of Gauff Hill, Lehigh County. They occur at elevations which Leverett regarded as higher than the Illinoian glacial deposits. On the other hand, they may be regarded as high-level alluvial deposits. All the materials are quartzite or sandstone and the cobbles are generally well-rounded. No doubt other occurrences exist, but can scarcely be discovered except when newly ploughed fields permit careful search in the surface soils. The interpretation and correlation of these deposits await further investigation.

The Lehigh County locality near Gauff Hill is characterized by an abundance of sandstone and quartzite pebbles and cobbles of various kinds. There is considerable black flint. Although most of the cobbles are well-rounded, there are many that are decidedly angular. The terrace-like bench where these materials appear in the fields suggests stream work. The area of the deposit is approximately half a mile long and one-eighth of a mile wide, with the greater length parallel to the trend of the mountain. At one place a low ridge parallel to the valley below suggests in appearance a moraine. The bench or terrace is slightly above the 700-foot contour.

Alluvial Deposits

As discussed under Physiography, there are alluvial deposits along the major streams and some of the minor ones. These are mainly Recent although some probably antedate the glacial deposits. They are generally thin.

Colluvial Deposits

The colluvial or hillside talus deposits are well-developed along the lower slopes of Kittatinny (Blue) Mountain and the gneiss hills in the southern part of the county and to a lesser extent on the minor hills. They are in process of accumulation and also destruction by weathering. Some of them may date back to the retreat of the glacial ice. In some of the deposits the blocks of stone are angular and of huge size. On South Mountain one can see many illustrations of exfoliation by which the blocks are changed into spherical boulders of gradually decreasing size.

Residual Deposits

The residual deposits of the region largely constitute the soils, which are discussed in another chapter.

STRUCTURE

By Benjamin L. Miller

The structural features of the rocks of Lehigh County are extremely varied and complex. Practically every type of geological structure is present. In places the structures have been determined with considerable certainty but in other sections they can only be inferred. The surficial cover of residual soils, talus and glacial debris conceals so large a portion of the strata that in places it is impossible to decide between different explanations that may be equally consistent with the known facts. New highway cuts, excavations and well drillings occasionally furnish desired information previously lacking. Present views are apt to be modified when and if new data in critical areas are obtained.

The present topographic features are the result of a combination of structural deformations and subsequent differential erosion. The hills are composed of rocks more resistant to erosion than the strata underlying the valleys, regardless of the original structures. The highest elevations in the county are produced by the resistant Silurian sandstones and conglomerates of Kittatinny (Blue) Mountain, almost the youngest rocks of the region, and the next highest hills are composed of the ancient pre-Cambrian metamorphic rocks.

Appalachian structure such as prevails throughout the entire Appalachian region is well exhibited in Lehigh County. Following the deposition of thousands of feet of sediments in the great Appalachian Paleozoic geosyncline, compressive forces became active and the strata were thrown into more or less parallel longitudinal folds. The dominant force came from the southeast and the resulting folds have a northeast-southwest trend. Both the basement pre-Cambrian crystalline rocks and the overlying sedimentary strata participated in the folding. The older rocks were uplifted in the anticlines far above the down-warped younger rocks in the synclines.

Open symmetrical anticlines and synclines exist in some portions of the Appalachians, but in this region the compression was so intense that the folds are generally closed and show marked asymmetry. The beds of the northern limb of the anticlines, or the southern limb of the synclines, are usually considerably steeper than the corresponding beds of the other side. In the slate quarries where the workable slate beds are mainly preserved in synclines, the quarrymen designate the steep south side as the "crop" and the more gentle northern limb as the "run."

So great was the compression in certain sections that the folds have been overturned, as will be presented in the descriptions of local structural features.

Few unmodified anticlines and synclines are present in the county, especially in the southern section where the folds involved older, more massive and, consequently, stronger crystalline rocks as well as the less resistant overlying sedimentary strata. In scores of places the folds are broken by faults (pl. 22-A). These range in magnitude from microscopic size to displacements of several thousand feet. The maximum fault displacement that has been determined is along the north side of Saucon Valley in the vicinity of Lanark where Jacksonburg limestone has been dropped 600 feet below the adjacent hill of gneiss, a total displacement of approximately 4,000 feet and probably considerably more.

The type of faulting in the region has long been discussed. Where there is evidence of faulting, some workers have interpreted the present distribution of the strata as due to reverse high-angle faults or low-angle overthrusts; others favor high-angle normal faults. Seldom are the fault contacts visible and the existing data do not permit a positive decision. In many places any one of these views might explain the observed facts.

The major faults, whether normal or reverse, tend to follow the general northeast-southwest trend of the strata. Where the present ridges consist of pre-Cambrian crystalline rocks, faults are common along the lower slopes of one or both sides. The actual faults are usually concealed by talus. The presence of these faults is determined by formations younger than the Hardyston in contact with the pre-Cambrian rocks or by discordant dips or strikes. Many of these faults are marked by springs or seepages.

The general structural pattern of the region, where the crystalline rocks and Paleozoic sedimentaries are both present, consists of ridges of pre-Cambrian rocks separated by generally narrow steep-sided valleys, although there are a few fairly wide flat-bottomed valleys. These valleys are normally floored by Paleozoic strata which have been down-folded or down-faulted or both.

Where only sedimentary rocks are present, such as prevail north of South Mountain, faults are indicated by lack of alignment of the outcropping formations. The structure, however, is of the same essential type.

The heterogeneous character of the rocks of the region and their consequent varying strengths have resulted in numerous modifications of the structural pattern. Even if the compressive force from the southeast were everywhere uniform, which is an improbable assumption, the resolution of forces due to unequal resistances of the rocks would cause buckling and breaking of the rocks along other directions than the major ones. This is seen in several places where folds and faults of varying trends are present. In places close folding, crumpling and faulting are so complex that it is difficult to explain the sequence of events even in good exposures, and impossible where outcrops are infrequent.

The dip and strike have been determined at practically every outcrop of the sedimentary strata unless the folding and irregularity of the beds are so complicated that the average conditions are indeterminate. Many of the structural observations have been recorded on the geologic map. An examination will show beds in close proximity with widely varying dip and strike. In general there is a predominance of southward-dipping beds which indicates overturning of folds to the north due to the compressive force coming from the south or southeast. If the surface cover could be removed, it is probable that axes of folds and directions of faults placed on the map would produce an almost inextricable tangle. A much larger scale than that of the present map would be necessary in order to represent them.

Whenever any company proposes to make any considerable use of any of the rocks of the county it usually becomes necessary to make a detailed investigation of the structure by surface trenching or by drilling. The information available from surface outcrops is generally too meagre in a region with such complicated structure.

It might seem that the greatest complexities would be in the weaker Paleozoic strata adjacent to the stronger metamorphic rocks of the pre-Cambrian. This is not always the case, as is shown in the illustration (pl. 22-B) of the intricately folded Beekmantown limestones at Ormrod.

The periods of folding and faulting in the district that occurred during the Paleozoic and Mesozoic eras are fairly definitely known. Those of the pre-Cambrian are only vaguely understood. Igneous activities, such as the up-welling of molten matter, were probably active agents in the production of some of the structural features of the pre-Cambrian.

Three known periods of deformation occurred since the opening of the Paleozoic and probably several during the pre-Cambrian. These are the Taconic Disturbance at the close of the Ordovician, the Appalachian Revolution that closed the Paleozoic era, and the normal faulting of the Triassic and post-Triassic. How effective the last of these was in this region is not definitely known. Faults are common in the great thickness of Triassic sediments that lie south of the county and it is believed that some of the faults outside the Triassic basins of sedimentation were similarly produced in Triassic or post-Triassic time.

Before discussing individual areas it seems well to refer briefly to an interpretation of South Mountain structure recently offered by Stose and Jonas[1] and discussed by Miller and Fraser.[2] According to this hypothesis most of the pre-Cambrian hills of the Reading region are part of a great overthrust block described as follows:

> Most of the mountain area from its end southwest of Wernersville to South Mountain south of Emaus, a distance of over fifty miles, and probably its extension across Pennsylvania to Easton, is believed by the writers to be a part of a great overthrust sheet which has ridden northwestward on a flat fault plane in the crystalline core of the mountains over lower Paleozoic rocks. (p. 763.)

The authors of this volume believe that all positive data on the subject as well as evidence of a probable character are opposed to the acceptance of such an interpretation for any portion of Northampton and Lehigh Counties as well as the area of Berks County northeast of Reading. According to Stose and Jonas the pre-Cambrian rocks of the region rest on Paleozoic rocks whereas all evidence in possession of the writers leads to the belief in the indefinite downward extension of the crystalline rocks.

Evidence in opposition to the great overthrust has been accumulating. Specific data from several localities will shortly be brought together and submitted for publication. The problem, which involves a much wider area than Lehigh County and the consideration of many factors does not seem appropriate for full discussion in this volume.

One example only is mentioned. Recent diamond drill holes in Saucon Valley, one of which was 1,447 feet in length, definitely prove that South Mountain does not rest on Paleozoic strata as claimed by Stose and Jonas-Stose. Other exact information in hand should completely discredit belief in a great overthrust block of pre-Cambrian in the region.

Although there are several recognized unconformities in the Paleozoic series of rocks, as shown in the columnar section, these do not seem to have greatly affected the present distribution of the different formations. The greatest occur at the contact of the Hardyston and the pre-Cambrian and at the base of the Brunswick. The Hardyston beds rest on the much older metamorphic rocks and the Brunswick slightly deformed strata were laid down on the beds that had been strongly folded and faulted in the Appalachian Revolution. Some were deformed during still earlier disturbances.

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[1] Stose, George W., and Jonas, Anna I., Highlands Near Reading, Pennsylvania: An Erosian Remnant of a Great Overthrust Sheet: Geol. Soc. Am. Bull., vol. 46, pp. 757-780, 1936.

[2] Miller, B. L., and Fraser, D. M., Geol. Soc. Am. Bull., vol. 46, pp. 2031-2038, 1936.

Evidence of a considerable break at the close of Martinsburg deposition has been presented elsewhere. The distribution of the Jacksonburg and the Martinsburg also indicates a period of erosion after the Jacksonburg had been laid down.

A few local studies of joints have been made, mainly in the slate region where they are of economic significance. The abundance and varying direction of joints in some of the limestones have rendered them less desirable for the quarrying of structural stone.

The structure section on the margin of the geologic map shows the general structural features of the area. It must be continually borne in mind that these are generalizations.

The pre-Cambrian and Martinsburg structures have been so thoroughly discussed by the writers of those formations that little more is added.

SECTION BETWEEN SOUTH MOUNTAIN AND THE MARTINSBURG

As shown on the geologic map, the formations between South and Kittatinny Mountains crop out in narrow to broad bands trending east to northeast. Northward from South Mountain the sequence of rocks is regular from the pre-Cambrian to the Silurian. Each formation in turn passes from view by dipping northward beneath the next younger series of strata. There are several local exceptions to this condition.

This general regular succession might imply simple structure, which is not the case. The geologists of both the First and Second Geological Surveys of the State clearly appreciated the complex structural features of the Lehigh Valley. J. P. Lesley[3] in 1875 aptly characterized the situation in the following paragraph describing the structures of the Cambro-Ordovician limestones.

> It seems a very easy matter to obtain the knowledge which we want in so open, well-formed, almost level valley, bounded on one side by a mountain faced by a well-known rock *underlying* the limestone (Potsdam s.s., No. I (now known as the Hardyston),) and in the other by hill slopes of unmistakable *overlying* slates (Hudson River, No. III (Martinsburg)). But what seems a facility turns out to be the principal difficulty. What seems so smooth and regular a surface conceals one of the most contorted, twisted, fractured, cleft, plicated, complicated and even overturned set of subsoil rocks in the world. Besides the three or four large and pretty regular anticlinal waves which issue from the South Mountain and the hills of Easton and strike diagonally westward up the valley toward Port Clinton on the Schuylkill, there are hundreds of sharp little rolls which seem to defy classification, and most of these are almost entirely concealed by a top covering of mouldered limestone clay, soil and vegetation.

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[3] Lesley, J. P., Report D, pp. 59-60, 1875.

Starting at South Mountain one should find the Hardyston everywhere cropping out near the base of the steeper slope. This is the case generally but in several instances the formation is absent on account of normal faulting. On the north slope of South Mountain as well as other hills of crystalline rocks the Hardyston is generally present but on the south side it is commonly missing on account of pronounced faults.

Overturning of the limestone strata can be seen in several places. An excellent example of this is exposed along the Lehigh Valley R. R. near Fullerton where Allentown limestones with specimens of *Cryptozoa* turned upside down are beautifully exhibited (Plate 25).

Complex folding in the Beekmantown in the vicinity of Coplay was at one time prominently shown, but the quarries with the best exposures are now largely filled with rubbish. Near Ormrod the Beekmantown is intricately folded in some places (pl. 22-B) and elsewhere the strata are overturned to the extent that the Jacksonburg dips beneath the Beekmantown (pl. 24-A).

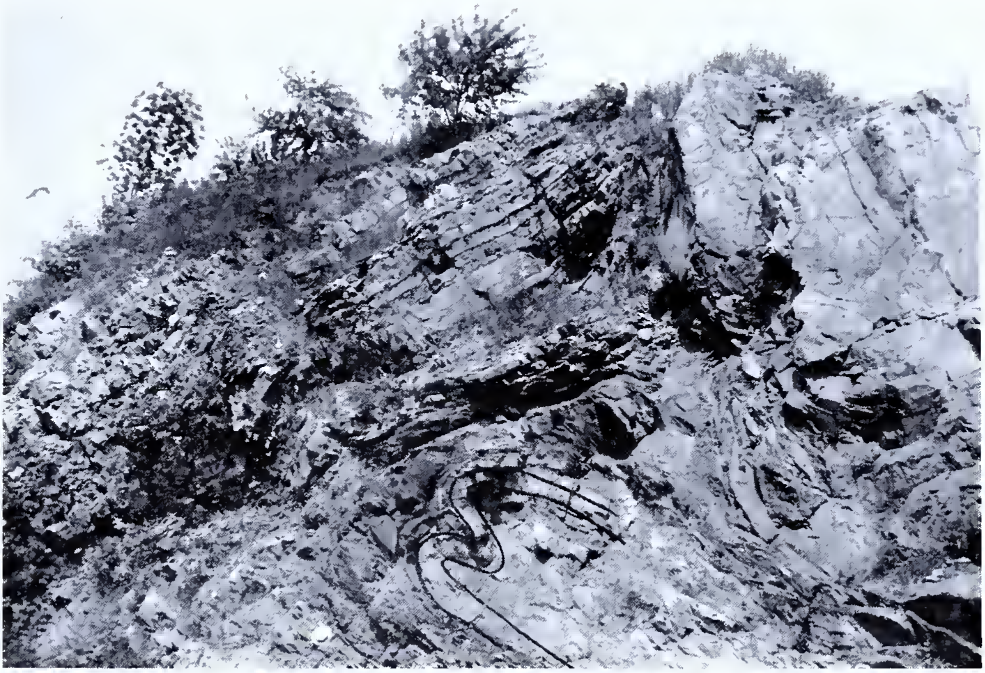
In the Beekmantown formation where dolomitic and low-magnesian strata are interbedded, a peculiar type of structure is developed. The relatively more competent dolomitic beds have been intricatly folded and show the character of the folding whereas the weaker low-magnesian beds were made sufficiently plastic by compression to deform by flowage, and old bedding planes are almost obliterated (pl. 23-B).

The Martinsburg slates have been greatly folded and in some places faulted. Fine examples of overturned folds can be seen in some slate quarries. The most important structural feature of these rocks, however, is the slaty cleavage. In some places it is not well developed but in others even the thin, interbedded, calcareous sandstones exhibit cleavage planes.

Both in the slates and the limestones it is common to find marked thickening of the beds at the anticlinal and synclinal axes and resultant thinning along the sides. Many fine examples of this kind can be seen in the slate quarries (pl. 34-B).

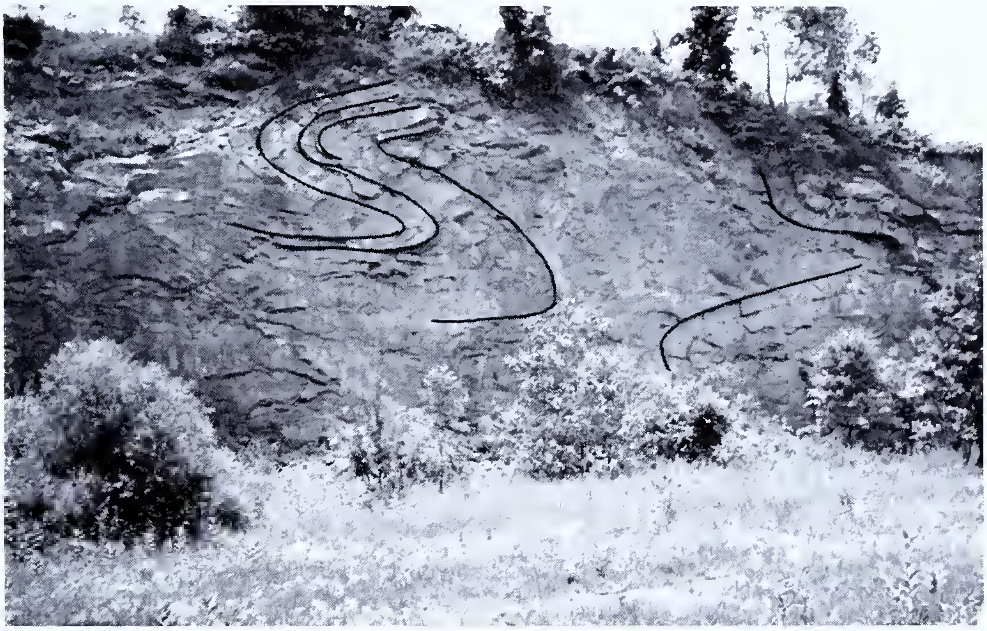
SAUCON VALLEY SECTION

The geological structure of Saucon Valley is complicated and is only partly understood. The major structure has been explained by some as a syncline and by others as a graben. It is probable that a combination of downward folding and faulting is responsible. The fairly regular occurrence of the Hardyston along the slopes of the gneiss hills in the eastern and southern boundaries of the valley with the Tomstown limestone adjoining suggests synclinal folding, whereas the almost complete absence of the Hardyston along the north sides gives evidence of faulting. The vertical displacement of 4,000 feet along the south side of South Mountain near Lanark, previously mentioned, is sufficiently great to account for the valley. With these facts it seems best to explain the structure as a syncline which has been profoundly faulted along the northern side of the valley.

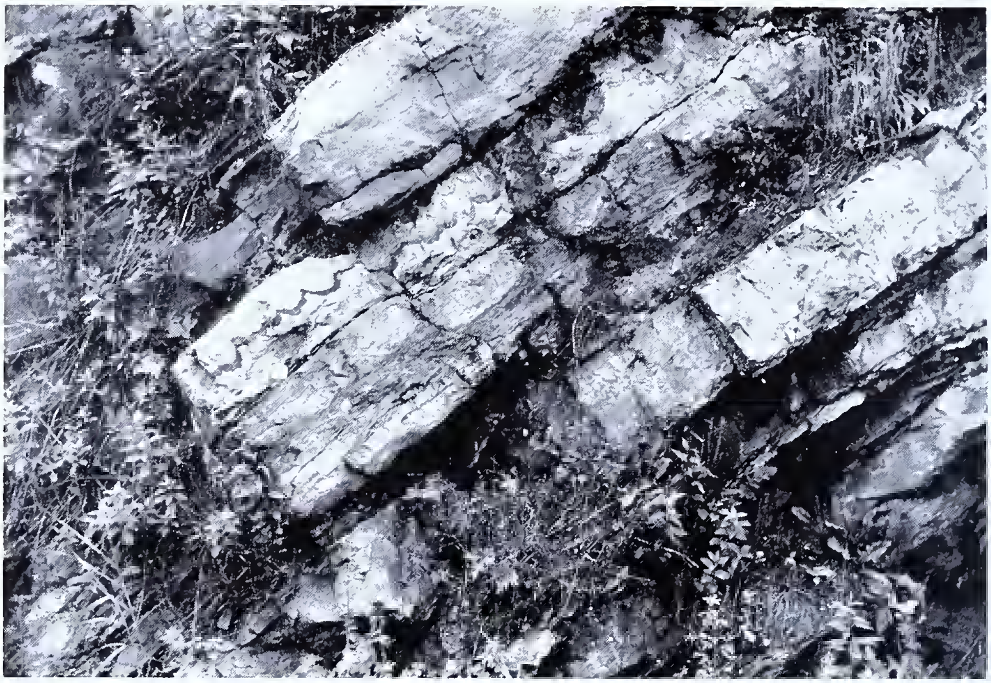


A. Complicated thrust faulting and folding of Tomstown thin-bedded and massive dolomitic limestones.

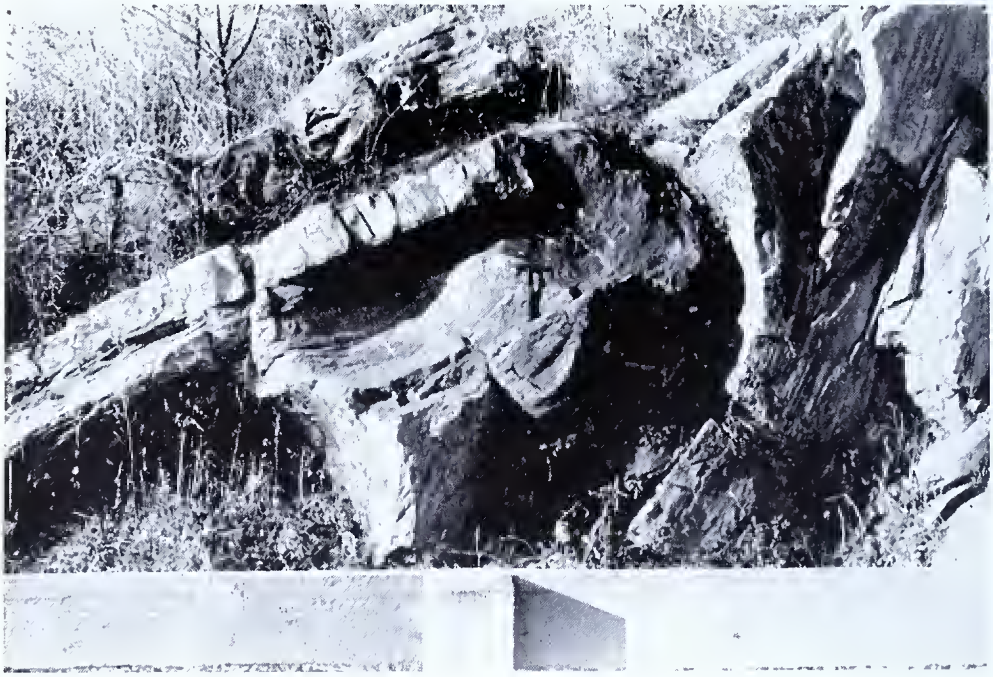
The strong massive beds have partly over-ridden and mashed the weaker thin beds. Along Central of New Jersey Railroad north of Hamilton Street bridge, East Allentown.



B. Complicated folds of Beekmantown limestone in abandoned quarry near Ormrod.

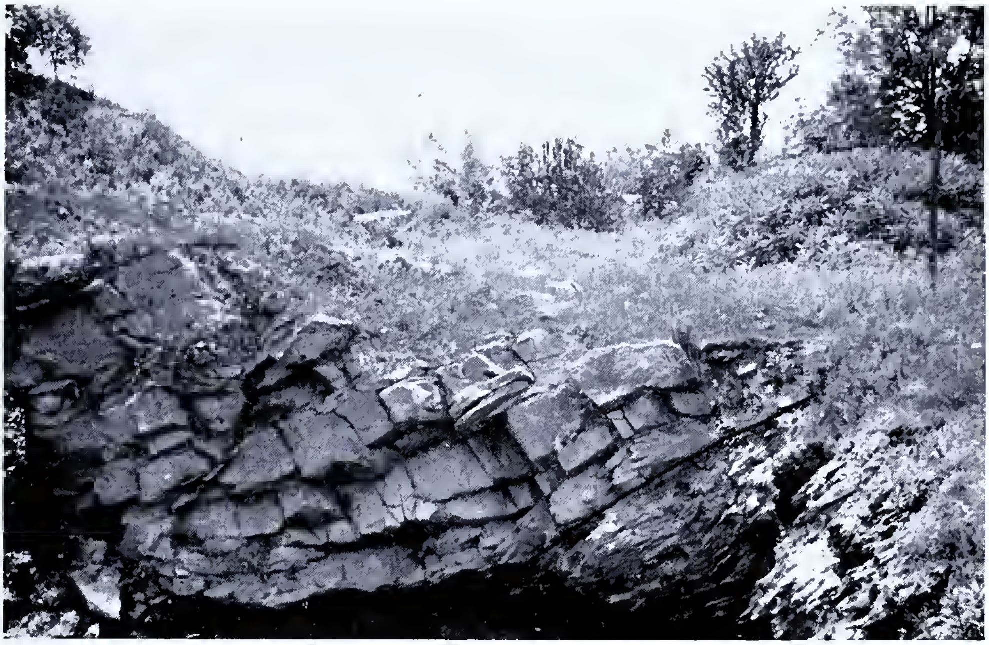


A. Overturned dolomitic limestones of the Allentown formation. Along Lehigh Valley Railroad below Fullerton. Note the upside-down *Cryptozoa.*

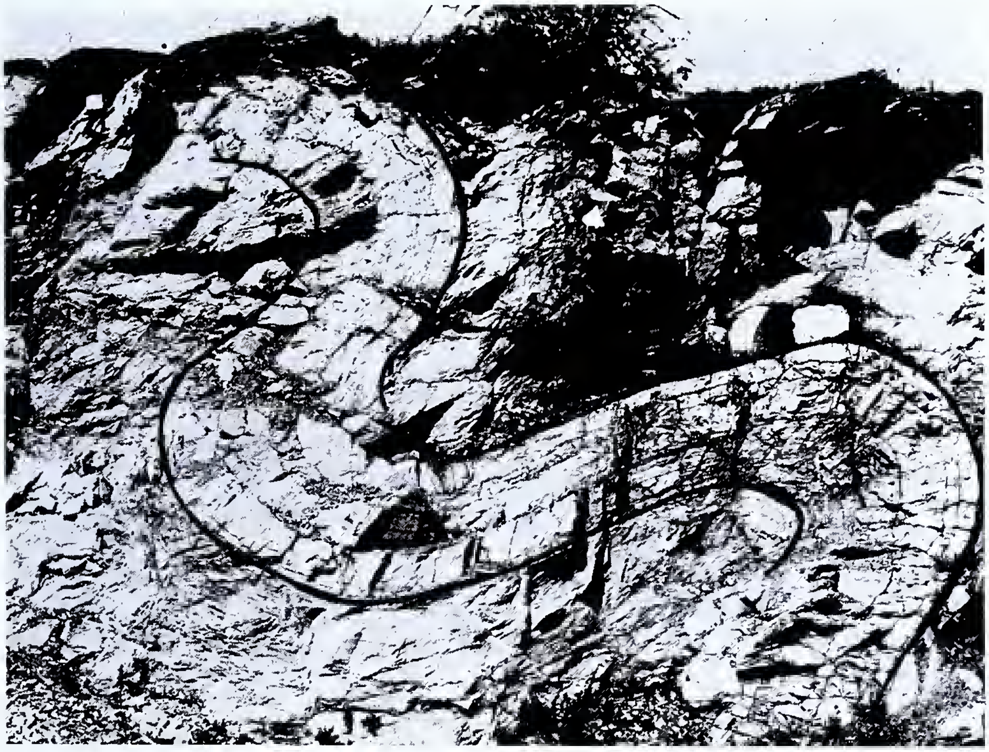


B. Bed of folded strong competent dolomite between weak low-magnesian limestones. Beekmantown formation, east Catasauqua.

The fold has been overturned to the north. The dolomite bed has been thickened at the crest of the fold. The low-magnesian beds have been readjusted by flowage.



A. Overturned fold at Ormrod. The Jacksonburg strata dip south and pass under the older Beekmantown formation.



B. Complicated folding of Beekmantown limestone strata, Coplay.

A. Recent view of the ruins of Lehigh Furnace west of Slatedale. Erected in 1826.

B. Old view of Crane Iron Company's furnaces at Catasauqua.

C. Limonite mines at Ironton while in operation.

MINERAL RESOURCES

By Benjamin L. Miller

Lehigh County contains a larger variety of economic minerals than most regions of similar area. This is explained by the variety of rocks present and the different conditions that have prevailed during the long period of time represented by them. The crystalline rocks of South Mountain are probably more than a billion years old and among the oldest known on the North American continent. In order of age they are followed by the Hardyston sandstones and quartzites of the lower slopes of South Mountain, the limestones of the Great Valley ending with the Jacksonburg cement rocks, the Martinsburg shales and slates of the northern half of the county, the Tuscarora sandstones and conglomerates of Kittatinny (Blue) Mountain, the Triassic red shales, sandstones and conglomerates of the extreme southern part of the county and the accompanying diabase intrusions, the glacial deposits in the northeastern part of the county and finally the alluvial sands and clays of the stream valleys that are still in process of formation.

Generalized geological column

Era	Age	Formation	Associated economic products*
Cenozoic	Pleistocene	Recent alluvial and residual materials	Sand, gravel, clay
		Glacial deposits of boulders, sand, and clay	Sand, gravel, clay
Mesozoic	Triassic	Brunswick red shales, sandstones, and conglomerates	Brick clay Building stone
Paleozoic	Silurian	Tuscarora sandstones and conglomerates	Building stone
	Ordovician	Martinsburg shales and slates	Slate
		Jacksonburg argillaceous limestones	Cement rock
		Beekmantown limestones	Limestone, building stone, iron ore, zinc ore, lead ore (?), manganese ore, ocher, pyrite
	Cambrian	Allentown limestones	
		Tomstown limestones	
		Hardyston sandstones and quartzites	Building stone, iron ore, pyrite
Proterozoic	Pre-Cambrian	Byram gneiss Pochuck gneiss Moravian Heights gneiss and schist	Building stone, iron ore, gold (?), pyrite, graphite, mica, corundum, quartz-mica schist, sand (decomposed gneiss)

* Ground water and soils omitted because common to all formations.

IRON ORE

The discussion of the iron ore resources of Lehigh County may appear to be of little importance because for nearly a quarter of a century past there has been no iron mining and for nearly a decade no iron furnace in operation. In this situation this description must be confined almost entirely to history. However, numerous matters of geologic interest are involved, and, further, there are reasons for believing that the time may come when there will be a revival of the industry inasmuch as other factors than exhaustion of the ore were responsible for the closing of most of the mines. If, and when, that revival occurs it will be useful to have available as complete a record as can now be made.

Although mining and smelting of iron ores have ceased, there are many iron-manufacturing industries in the region, of which a considerable proportion is contingent upon these bygone activities. Their location was largely determined by the existence of workable iron mines nearby. The decline of iron-ore mining not only in this county but also throughout the State and adjoining States is one of the best examples of the rise and decay of important industries and the interrelationship of varied economic factors.

The earliest record of iron ore in the United States concerns a shipment from Jamestown, Virginia to England in 1608. The earliest known Pennsylvania record of iron from local ores was in 1692. Before the Revolution iron mines, forges, and furnaces were in operation in some of the counties adjacent to Philadelphia, but not until 1809 do we have record of any in the region now Lehigh County. During the next hundred years, iron mines and furnaces were widespread within the county. The greatest activity seems to have been from the close of the Civil War to about 1885. A gradual decline took place in the latter part of the last century and the first part of this century. The furnaces were built for the purpose of smelting local ores but they survived by a few years the last operation of the mines. Magnetite ores from northern New Jersey and finally hematite ores from the Lake Superior district gradually, and eventually, entirely, replaced the local ores.

Only as one drives through the county and observes the numerous old mine holes and mine dumps can he realize the extent and distribution of former iron mines. Altogether 258 old limonite iron-ore mines have been located on the accompanying map. Magnetite and hematite mines also were opened in a dozen or more localities.

In the census of 1880 Pennsylvania led all the States in the production of iron ores, and Lehigh County led all the counties of the State. In that year the county produced 359,302 tons of limonite ores and 70,398 tons of magnetite.

History

Inasmuch as furnaces had to be erected before it became economical to work the ore mines, the first consideration is given to their history. Two conditions were important in their location, the proximity of ore mines and of timber for making charcoal. All the earliest furnaces used charcoal. In 1840, however, at the Catasauqua furnace of the

Crane Iron Co., David Thomas proved that anthracite could be substituted for charcoal. Several decades later, improved railroad transportation permitted the shipping in of coke or bituminous coal from which coke could be made.

In most cases all the ore mined was hauled by wagon to the furnaces. This heavy traffic is said to have resulted in almost impassable roads during wet seasons. The construction of the Catasauqua and Fogelsville Railroad, which was opened in 1857 to Ruppsville (Rupps Station) and later extended to Rittenhouse Gap, was of the greatest importance in the transportation of ore to the furnaces at Catasauqua, Hokendauqua, and Alburtis. Similarly the East Penn Railroad from Reading to East Penn Junction, completed in 1859, served another group of mines near Macungie, Alburtis, and Emmaus. The Ironton Railroad from Coplay to Ironton was completed in 1860. These three railroads and some short spurs reduced the transportation difficulties materially by shortening the wagon hauls. Later these railroads acquired much greater importance in the transportation of other commodities, especially cement.

EARLY FURNACES

So far as known the first iron furnace erected in Lehigh County was the Hampton or Sigmund Furnace, located at the place now known as Sigmund, on a branch of the Perkiomen Creek, in Upper Milford Township, close to the Berks County line. It is at the base of Furnace Hill, which, obviously, was named for the furnace. It was built in 1809 and was operated until 1868.

The first owners were David Heimbach and two other men, Wisserman and Coverly. Heimbach, however, soon bought the holdings of his partners and operated the furnace until August 13, 1832. It changed hands several times before February 7, 1850, when it was acquired at sheriff's sale for $3,525 by Frederic Sigmund, who was in charge until his death in 1860. His sons operated it until 1867. At this time it became known as Sigmund's Furnace, although originally given the name of Hampton Furnace. In 1867 it was acquired by Peter Faust, who closed the furnace and erected a powder mill on the site. The mill was wrecked by an explosion three years later.

Stove plates were made in the early years. Later the entire product was pig iron. The furnace had small capacity. In 1857 it produced 722 tons of "first-class car-wheel iron" in 28 weeks.

Some of the ore used in the furnace came from mines in Berks County, some was hauled from the iron mines at Ironton, and probably from mines in other parts of the county. The charcoal was made locally and the limestone for flux was obtained from some near-by quarries on both sides of the Berks-Lehigh County line.

In 1826 the Lehigh Furnace (pl. 25-A) was built near the base of Kittatinny (Blue) Mountain in Washington Township because of the proximity of charcoal supplies and water. The ore is said to have been hauled from iron mines in South Whitehall Township. This furnace, which was operated until about 1880, also was of small capacity. "In 1857, during 26 weeks, it produced 554¾ tons of pig-iron."

Stephen Balliet and Samuel Helffrich built the furnace and operated it until Helffrich's death in 1830. Balliet operated it until his death in 1854. Cooper and Hewitt were the last owners.

The Crane Iron Company (first called the Lehigh Iron Co.) started its first furnace at Catasauqua in 1840 (pl. 25-B). In it for the first time the substitution of anthracite for charcoal proved to be entirely successful. This is attributed to the skill of David Thomas, who was brought from Wales for this particular purpose. The anthracite was brought from Mauch Chunk by canal boats. Additional furnaces were built in the years 1841, 1846, 1850 (two), and 1921. The last one, with a daily capacity of 400 tons, was the largest. Operations continued only about a year after its erection. This company seems to have smelted more local ores than any of the other companies. For over 80 years the Crane brand of pig-iron was constantly in the market.

The Allentown Iron Co. (also known as the Allentown Iron Works and Lewis Furnaces), with its plant along the Lehigh Valley Railroad in Allentown, started a furnace in 1846. Other furnaces were built in 1847, 1852, 1855, and 1872.

The Lehigh Valley Iron Co. (later the Coplay Iron Co.) operated a furnace at Coplay from 1854 to 1873, producing about 6,000 tons of pig iron a year.

The Thomas Iron Works (later the Thomas Iron Co.) built a furnace at Hokendauqua in 1855 and became one of the principal iron establishments of the county. Six different furnaces were built here between 1855 and 1874. M. S. Henry, in his History of the Lehigh Valley (1860), gives the combined capacity of the first two furnaces as follows:

> The largest yield of the two furnaces for any one week was 605 tons and for one furnace in one week 351 tons, an amount unprecedented in the annals of iron making. (p. 300.)

These furnaces continued to operate until 1927.

The Roberts Iron Co. (later known as the Allentown Rolling-Mills Co. and in 1914 acquired by the Aldrich Pump Co.) built two furnaces along the Lehigh Valley Railroad in Allentown, the first in 1864 and the second in 1865.

The Lock Ridge Iron Co. near Alburtis started its first furnace in 1868 and a second one in 1869. This company was acquired by the Thomas Iron Co. and the furnaces were designated as Nos. 7 and 8. They were dismantled in 1923 and 1924.

The Lehigh Iron Co. operated two furnaces at the bend of the Lehigh River in southeast Allentown from 1869 to 1906. The first was started in 1869 and the second in 1872. Both were later rebuilt. They were dismantled in 1909.

The Millerstown Iron Co. (later the Macungie Iron Co.) operated a furnace at Macungie (formerly Millerstown) intermittently from 1874 to 1913. The property changed hands a few times and was sold twice by the sheriff. The Empire Steel and Iron Co. finally acquired and operated it from October 1912 to May 1913. Later it was scrapped.

The Crumwold Furnace at Emmaus was built by Robert Coleman and put in operation on October 10, 1872. It was rebuilt in 1879-80 and remodeled in 1890. In 1898 the property was sold to the Reading Iron Company, which operated it until 1923. It was dismantled in 1927-1928.

Sheet III of Topographic Map of the Durham and Reading Hills, published by the Second Geological Survey of Pennsylvania in 1883, shows a furnace about half a mile east of Vera Cruz Station at or near the place where a tunnel was driven into the hill to cut the magnetite ore bodies. Residents familiar with the region since 1865 are positive that there never was a furnace there. This seems probable, as no trace could be found of any ruins or of any slag.

These various furnaces were supplied mainly or entirely by local iron mines at the beginning of their operations. Most of them survived several years after all local mining had ceased. They were at times highly successful and found a ready market for the pig iron. Their doom was sealed, however, when in the early 1920s the larger iron and steel companies of Bethlehem, Reading, Philadelphia, and elsewhere increased the capacity of their furnaces to supply all their own requirements for pig iron and, during slack periods, to sell pig iron to others. The local furnaces could not compete and, one after another, all were closed and scrapped. Naturally the Bethlehem Steel Co. was mainly responsible for the closing of local furnaces in Lehigh County.

Numerous slag heaps, some very large, now furnish almost the sole visible evidence of the former existence of these furnaces. In recent years some of the slag has been utilized for ballast and concrete aggregate. Near Glendon, Northampton County, mineral wool was made from old slag, but no attempts have been made to utilize any of the Lehigh County slag for this purpose. At times the question of its adaptability for the manufacture of portland cement has been raised. It is doubtful whether any of the slags in this region are suitable for this purpose because of their high magnesium content. This is due to the use of local dolomitic limestones for flux.

EARLY IRON MINES

In the "History of Lehigh County, Pennsylvania," by Roberts et al., published in 1914, descriptions are given of the early iron mines in different parts of the county. Two of these descriptions are here quoted:

> Iron ore was first found in North Whitehall about 1800, upon land originally owned by the Scheurers and the Woodrings, where Ironton now stands. It lay in lumps upon the surface, some large bowlders weighing several tons, and found in such profusion that its presence was a serious impediment to the prosecution of agriculture. Some of this surface ore was taken to the Richard and Regent Furnace at Hamburg and exchanged for pig-iron; some was turned into nails by hand at the forge of Adam Scheurer; some loaded upon four horse teams and sold at twenty-five or fifty cents a load; some taken to Mauch Chunk with teams and exchanged for equal weight of coal. Between 1812 and 1826 the ore was taken to the old David Heimbach forge at Hampton, in Milford township, and to Clarissa Furnace near Little Gap, on the Aquashicola creek, in Lower Towamensing township. About 1826 the Lehigh Furnace at the base of the Blue mountains

> was built by Stephen Balliet and Samuel Helffrich, and then the surface ore was exhausted. Digging was commenced by Reuben Trexler and Abraham Lesher, and their venture proving unprofitable, the work they began was continued by the managers of the Maria Furnace near Parryville, and of the Henry Furnace at Nazareth. These furnaces for a time received all the products of the mines. Some of the ore was taken to the Lehigh Furnace, which was filled with this ore from North Whitehall, and first blown in during the fall of 1826. The mining was carried on by sinking a shaft and then drifting, taking out lump ore only. These original mines were the orepits styled Nos. 1 and 2, immediately north of Ironton, and belonged to the Thomas Iron Co., of Hokendauqua. The Joseph Balliet mine below Ironton was next opened, afterward owned by his heirs and Frank P. Mickley. In opening this the miners came across several of the tunnels which had been made in developing the original Ironton mines.
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> The first apparatus for screening ore was made by Fritz Guth, an ingenious German, who was persuaded by Stephen Balliet to immigrate to this country, and who lived for many years near Ruchsville. He was also the inventor of improving the blast in the charcoal furnaces used at that day. (vol. I, pp. 853-854.)
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> Another extensive industry in days gone by was the mining of hematite iron-ore. Within a few years previous to the "financial crash" of 1874 very rich and valuable deposits of this ore had been discovered in the township (Lower Macungie). The mining fever seized the people. Leases were made, shafts sunk, and the hidden treasure sought after everywhere. Ore-washeries sprung up abundantly. Many a farm was partly laid to waste, but no one cared as long as the returns came in the shape of rich royalties. Let coming generations gaze upon the unsightly holes in beautiful fields, and strive to bring the mud-dams back to a state, so as to reward the husbandman for his labor expended. The section, known as the "Flats," situated eastward from East Texas was especially devoted to this mining fever. About a score of washeries were located in the space of a couple of city blocks. The region had been originally covered with scrub-oak. A number of people had been making their livelihood by grubbing the same by the day, and thus getting the land in shape for agriculture. These had been lamenting that the days of their livelihood would soon be undone, when the discovery of the ore, opened up the "golden age" for them. However, now one can traverse the township from one end to the other, and scarcely anywhere even find the abandoned ruins of what were once active washeries. A goodly portion of the land has been reclaimed for agriculture, nevertheless many an acre will lie barren, because the expense of reclaiming would be almost unwarranted. At present it can be said that the principal industry of the township is that of agriculture. (vol. I, p. 757.)

The earliest description of the geology of the iron mines is by Henry D. Rogers in his "Second Annual Report on the Geological Exploration of the State of Pennsylvania," published in 1838.

> About five miles northwest of Allentown, and three from the river Lehigh, are large deposits of ore, which have been rather actively worked for the last ten or twelve years. The predominant variety here, is the brown hydrated peroxide of iron, though the red oxide is also abundant. True brown hematite, and a variety of jaspery iron ore, are likewise not uncommon. The material in which the ore is imbedded, is a ferruginous clay, resting over the limestone. A white clay, and an impure ochre are also associated as in the case below Belvidere. None of the excavations have yet reached the subjacent rock. The mining is done either by shafts, or when the configuration of the ground permits, by simply quarrying in the open air.
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> Iron ore is found in moderate abundance, and of excellent quality in the neighborhood of Emau's, five miles south-west of Allentown. It occurs in clay, no rock being very near it. The ore presents fewer varieties in this place than at the mines last mentioned.
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> About a mile and a half west of Trexlerstown, in Lehigh county, in a tract where the surface of the limestone formation is quite level, there

is a very large deposit of iron ore, some of which, without altering its external structure, which is that of the cellular and pipe ores, has passed to the condition of sulphuret of iron, or the common *copperas mineral.* This mine was originally worked for the iron ore which it contains, this being still an object of pursuit; * * *.

Generally the pure iron ore, and the sulphuret of iron or copperas mineral, occur separately, or in different layers of the same stratum, the sulphuret in the lowest position.

The ore is of very good quality and of several varieties; among these, are the brown hydrated peroxide, having the forms of compact, cellular and columnar or pipe, ore; and the red hydrated peroxide, the structure and forms of which are no less diversified.

This mine is further described under Pyrite.

To attempt to specify in this place the very numerous localities in which the superficial appearances indicate the probable existence of more or less extensive deposits, or even to enumerate the many excavations, some of which are quite large, where the ore is daily procured, would be incompatible with the scope of the present report. It may not be amiss, however, to mention one or two particulars respecting the manner in which it occurs.

It appears to be a general rule, that by far the largest and most numerous deposits of the ore belong to that half of the limestone belt which is next to the South Mountain. This is, however, not without exceptions, a signal instance occurring in the rich ore tract which lies about five miles north of Allentown, and a little west of the Lehigh, and which is but a short distance south of the northern margin of the Limestone at its junction with the slate.

No part of the whole limestone belt of the valley indicates the presence of so large a quantity of iron ore below the soil, as the district which lies a few miles south-west of Allentown, particularly in the vicinity of Trexlerstown. To allude to the circumstances which usually betoken an abundance of this kind of ore, one of the most obvious, would seem to be considerable depth for the deposit of ferruginous loam, clay, or other earth, resting on the rocks of the district. This will of course be marked by a corresponding evenness of the surface, for where the strata of the limestone are naked of soil in many places, it implies that the covering of earth which contains the ore can nowhere be deep. Another very essential condition is, that the earth overlying the rocks should have a large amount of the oxide of iron diffused throughout it. This will shew itself by its characteristic bright yellow, or yellowish brown, colour. It must be observed however, that the existence of a large quantity of oxide of iron in the deeper part of the soil, will very frequently not be perceptible in the colour of the surface of the ground, being confined to the lower layers, so that much good ore land is often neglected from want of enterprise to dig sufficiently deep.

The hydrated brown and red iron ores, of the principal limestone tracts of our State, I conceive to have originated almost entirely, from the filtration of water through deposits of soil rather richly impregnated with the particles of the peroxide of iron. This I think is proved, by the peculiar structure of the ore itself, which not only puts on the form of stalactites and stalagmites (concretions of carbonate of lime, produced by the dripping of water,) but precisely those slight variations from these forms which ought to arise from the influence of the particular composition of the surrounding material,—clay or loam, or sand,—in modifying the manner in which the water would filter through the mass, and deposit the ferruginous particles.

The earth containing the ore, I suppose to have been a *sediment* from that mighty mass of waters which evidently once overspread all our formations, and which derived the materials of this deposit, if we judge by their nature, from the subjacent limestone and the contiguous sandstones. Thus we may at once discern why the largest and richest accumulations of iron ore, are on the side of the valley next the base of the South Mountain, for all independent Geological evidence concurs to shew, that the waters which I imagine to have left this deposit, flowed towards this quarter from the north, while the level of the valley being most depressed on this side, we ought naturally to look here for the deepest collections of the heavy ferruginous sediments in which the iron ore is principally found. (pp. 26-28.)

Types of Iron Ore

Three different kinds of iron ore have been worked in Lehigh County. They are (1) the black magnetite ores of the pre-Cambrian crystalline rocks, (2) the brown to yellow limonite ores of the Hardyston sandstone of Cambrian age and the Cambro-Ordovician limestones and (3) the gray siderite (carbonate) ores found in association with the limonite. Other iron minerals associated with the limonite are occasionally noted, such as goethite, turgite, and pyrite. Of these three types, the limonite and magnetite alone are of importance, although a small amount of carbonate ore has been mined and shipped.

Limonite Ores

The limonite ore of the region was generally known to the iron workers as "brown ore," "hematite" or "brown hematite." Since the ores are all hydrous, obviously "hematite" is a misnomer.

It has long been the custom to divide the limonite ores into two classes, the mountain ores and the valley ores. This division is justified by their occurrences and, to a minor degree, by their physical and chemical characteristics.

DISTRIBUTION

Mountain ores.—The mountain ores are confined to areas where the Hardyston strata crop out. These areas are the lower or middle slopes of the mountains of the southern part of the county. They are especially abundant on the north slope of South Mountain between Emmaus and Mountainville.

Mines are numerous in certain areas of the Hardyston, but are lacking in others where the formation is equally well developed. The metamorphic changes that the formation has undergone locally since its deposition have determined the places where ore has been deposited. In the areas where the ore deposits occur, many of the original sandstone strata have been changed into jasperoid rocks, although certain conglomeratic strata remain practically unchanged; but in places where ore deposits are absent the formation is composed entirely of ordinary sandstones and conglomerates. It is therefore considered useless to prospect for iron ore of this type in areas where the irregular masses of yellow to red jasperoid rocks are absent in the soils.

Valley ores.—The limonite ores are extremely irregular in their distribution. In general they are more abundant in the southern part of the limestone valley where the Allentown dolomitic limestone is the most important formation, but marked exceptions are the regions of the Beekmantown limestone of Ironton, Guthsville, and Fogelsville.

There seems to be some relation between the structural features of the rocks and the location of the ore deposits, for as a rule the largest deposits of ore are found in places where the limestones have been closely folded or faulted. As the rocks are likely to be much more shattered at the crests of closely folded and eroded anticlines, such places should be more favorable for ore deposition, and the investigations in this region indicate a relationship of that kind. In general, those places in the limestones where the underground waters have collected and flowed with greater freedom are the places where the ore was deposited in largest amount. Miners frequently remark upon the observed connection of underground watercourses and the limonite deposits. As a rule, throughout the limestone regions good wells can be procured in few places at depths less than 200 feet, and yet few good iron mines have been opened where the volume of water encountered at depths of 100 feet or even less was not an obstacle to the development.

Limonite deposits are not found in the valleys of the main streams but are common in local depressions in the general upland surface where sink-hole topography is noticeable. As the glacial deposits are usually thicker over the ore deposits than in the surrounding region it is probable that depressions existed there before the glacial epoch.

OCCURRENCE

All the known limonite ore deposits of Lehigh County are surficial or shallow. They are irregular in extent and either occupy pockets in the underlying rocks as much as 100 feet or more in depth, or follow certain strata that more readily yielded to solution or replacement. In the belt of ''mountain'' iron mines along the north slope of South Mountain certain strata were converted into iron ore more or less completely for about three miles, and the ore bodies consequently are parallel to the adjoining strata both in dip and strike. In other places, however, the ore formed irregular masses which bear little relation to the structure of the surrounding rocks, so far as can be determined. Usually, however, the greatest diameter of the ore body is parallel to the strike of the enclosing strata.

The position of the mountain ores near the base of the mountains formed of gneiss causes them in most places to have a surface cover of float rock from the higher ground, and consequently the ore appears at the surface in but few places. This talus cover may be so deep that the ore can be worked only through shafts.

In some places the valley ores are concealed by deep deposits of glacial material that render their discovery difficult, but most of the bodies of ore thus far worked were located by the float ore in the soil. Good ore in many mines was reached within a few feet below the surface. In some freshly plowed fields the soil in the vicinity of a body of limonite ore is a rich brown that can be easily distinguished at a distance. Most of the ore bodies in the limestone valleys have been discovered by sinking test pits in places where the soil was deeply colored and pieces of float ore were abundant. Bodies of workable ore have also been discovered by sinking test pits along the line of known deposits or in the vicinity of sink holes.

The ore has been found as much as 175 feet below the surface, which was approximately the maximum depth of the mountain ore mines, owing to the difficulty of keeping them free from water and also owing to the tendency for the shafts and drifts to be closed or rendered dangerous on account of the squeezing action of the clay associated with the deposits, which slowly moved downhill when saturated with water. It is probable that few of the bodies of limonite ore extend much below the ground-water level and that they scarcely exceed a maximum depth of 300 feet, which is deeper than any of the mines of the region. In many of the valley-ore mines the limonite occupied shallow basins in the limestones and solid limestone was found at depths less than fifty feet. Rock in place is now exposed in many of the old limonite pits. In the mountain-ore mines the ore became leaner or changed to ore high in sulphur in lower levels but still continued to the greatest depths reached.

The iron ore is almost invariably associated with quantities of white, yellow, or bluish-black clay formed by the decomposition of shaly strata which are interbedded with Cambrian sandstones and quartzites and the Cambrian and Ordovician limestones. Besides the clay, masses of jasperoid quartzite are commonly encountered in the mountain-ore mines, and small and large rounded segregations of black chert occur in the valley ores. The fragments of jasper represent portions of the original Cambrian sandstone that have undergone less alteration.

Within the clay the iron ore occurs either in the form of isolated masses or in rather definite veins that have a maximum width of forty feet. Even in the best ore bodies, considerable clay and ocher are present, ranging from one-third to one-fourth of the material removed from the mine. In the average mine the clay washed from the ore constituted from 50 to 75 percent of the product. The ore in the veins invariably is cavernous and contains considerable clay within the cavities.

Yellow ocher is almost everywhere associated with the ore, as would be expected, for ocher is an intermediate product between the clay and the iron ore. In the ocher the limonite has not been segregated but occurs in the form of finely disseminated particles intimately mixed with the clay.

PHYSICAL CHARACTER

The limonite ore occurs in several different forms, some of which have received distinctive names by the miners, such as bombshell or pot ore, pipe ore, and wash ore.

The bombshell or pot ore consists of more or less spherical masses of limonite that range in diameter from one inch to two feet. They are geodes of limonite; many of them are hollow or filled with water and others are fairly well filled with white or drab clay or fine white to pink sand. The interior of these geodes almost invariably presents a black lustrous botryoidal surface, which in some specimens is markedly iridescent. The dark color of the interior suggests the presence of considerable manganese, and analyses commonly show this metal to be present, although the lacquer-like surface is mainly, if not entirely, composed of goethite. Tiny stalactites of limonite occur in many of the geodes. The walls of the bombshells range from considerably less than an inch up to an inch or more in thickness and in most specimens show a fibrous radiating structure in the inner layers. Some of the geodes contain sand grains firmly cemented by iron oxide, but others are practically free from any siliceous particles that can be detected by the eye. In general, the bombshell ore is the highest grade ore obtained and can be readily freed from any adhering clay by washing. Many of the geodes consist largely of iron carbonate (siderite), and in a few mines the bombshell ore is called carbonate ore. Invariably, however, limonite also seems to be present, especially in the inner layers. The carbonate bombshell ore is gray when mined but later becomes brown as the carbonate changes to limonite on exposure. In some geodes the stratification of the original sandstone or limestone is preserved in the enclosing walls.

Closely related to the bombshell ore are the large irregular masses of cellular material that form the bulk of the limonite ores. These masses are from a few inches to ten feet or even more in diameter and consist of a network of thin partitions of limonite running in every direction. The cavities usually are small, as a rule not more than a few inches in extreme length, are exceedingly irregular in shape, and are commonly filled with an ocherous clay. The walls of the cavities are coated with a firmly cemented layer of the ocher. The character of this ore renders it possible for the miners to break the large masses readily with pick and sledge.

Some of the mountain ores occur as masses of porous limonite roughly arranged in parallel layers and resemble in structure pieces of rotten wood. The layers probably represent the stratification lines of the original rocks. Tiny stalacites of limonite are abundant between the layers.

Small pieces of cellular ore in which the cavities are rectangular are occasionally found. These specimens represent the segregation of limonite in joints of the original rock, the partial replacement of the original rock, and the subsequent removal of the remainder through solution. Some of the longer tubelike masses are called pipe ore, although true pipe ore is somewhat different. In some places the original rock remains, surrounded by a shell of limonite. In the mountain-ore mines pieces of limonite enclosing sandstone are not uncommon.

In many places the original sandstone of the mountain ores seems to have been broken into angular fragments, probably owing to the contraction of the mass as it changed to jasper, which usually preceded the formation of the ore. These angular fragments have later been cemented by limonite that was precipitated in the cavities and forms a limonite breccia. In many specimens fragments of sandstone or jasper have themselves later been replaced by limonite. In ore of this kind small particles of secondary vein quartz are more common than in the other kinds of ore, although quartz is not common in any of the limonite ores. The secondary quartz shows that part of the siliceous material removed by the solution of the original rock was precipitated in the cavities of the iron ore.

In the valley-ore mines, tubes of limonite that enclose more or less sand are common. This variety is known as pipe ore and was the principal ore mined in many places. The largest tubes are a foot in diameter, although most of them range from one to two inches. Pieces more than eight inches long are rare but as the pipes are invariably broken at each end they may originally have been several feet long.

Fragments of limonite in the form of irregular particles or plates are invariably present in large quantities. They represent broken pieces of all the kinds of ore that have been described. As the rock disintegrates and clay and iron ore are formed, there is a tendency for the entire mass to move down the slopes, which results in the breaking of the more fragile pieces of ore. The loss in bulk that takes place as the rock undergoes changes in composition also permits the downward settling of the material and the breaking of many of the masses of ore. The larger pieces of the fragmental ore are recovered in the washers, but the finer ones are lost. Ore of this kind is known as "wash ore."

CHEMICAL COMPOSITION

Minerals associated with the ores.—The composition of the limonite ores is extremely variable and depends largely on the physical character of the material. The presence of certain minerals closely associated with the limonite also determines the composition. The impurities in the ore comprise only a small number of minerals, principally quartz, jasper, clay (kaolin), pyrite, pyrolusite, and wavellite.

Siliceous matter of different kinds can be detected in almost all the mountain ores. In some places it represents the fine grains of sand of the original sandstones or sandy limestones, in others secondary chert or jasper, and in still others vein quartz. Clay fills many of the cavities in the ore, and much of it is not removed in passing through the log washers. Very small particles of pyrite can be seen with the naked eye in some specimens, particularly in the ore from the lower levels of certain mines.

Pyrolusite is intimately associated with the limonite and is generally detected by the dark color of the ore. Occasionally dendritic crystals of pyrolusite form a thin cover to the limonite. In general the mountain ore contains a higher percentage of manganese than the valley ore.

Most of the phosphorus in the ore is probably contained as aluminous and iron phosphates, such as wavellite $[(AlOH)_3.(PO_4)_2.5H_2O]$ and cacoxenite $[FePO_4.Fe(OH)_3.4\frac{1}{2}H_2O]$.

Mountain ores.—Although the sulphur usually is low, some mountain-ore mines had a large amount of pyrite in the lower levels. It is probable that deeper workings may show an increase of pyrite in almost all the mines, but the decrease in the content of iron and the increased expense of mining has prevented the exploration of the lower portions of the ore bodies in most places. Examination of hundreds of analyses made by the chemists of the Thomas Iron Co., the Bethlehem Steel Co., and the Crane Iron Co. shows that the mountain ores average about 40 percent iron, 20 percent silica, 0.4 percent phosphorus, 0.2 percent sulphur, and 3.26 percent manganese. The iron content ranges from 32 to 54 percent. Very little ore was used which contained less than 36 per cent iron, and a few mines have furnished much ore that ran as high as 50 percent iron. The ores are characterized by a high percentage of silica, ranging from 15 to 30 percent. The phosphorus is usually too high for Bessemer steel; in much of the ore it runs up to approximately 1 percent.

Perhaps the most distinctive feature of the mountain ores is the high content of manganese, which ranges from 2 to 4 percent in most of the mines but may run as high as 15 percent in places, and pieces of practically pure pyrolusite are occasionally found. For this reason the mountain ores were always in demand by the furnaces making basic iron.

Valley ores.—The valley ores differ somewhat in composition from the mountain ores. These differences are mainly in the greater amount of silica and manganese in the mountain ores and the greater amount of magnesia and phosphorus in the valley ores. Most of the ores, after washing to remove the bulk of the loose clay, averaged slightly more than 40 percent metallic iron and ranged approximately from 35 to 50 percent.

ORIGIN

Processes of formation.—Although the limonite iron ores of the Appalachian region have been discussed in hundreds of articles, there is still no entirely satisfactory explanation of their origin. Many investigators have shown a tendency to regard all of them as having a similar origin, which is an incorrect view. Even in a single mine, evidence can sometimes be obtained to prove that limonite has been formed by the oxidation of pyrite, by the oxidation and hydration of siderite, by the replacement of limestone or sandstone, by the segregation of particles of disseminated limonite, or by precipitation in open fissures or other cavities. Under such conditions it is obvious that a theory that attributes the origin of these ores to one process of formation is not sufficient even for certain single deposits and is entirely inadequate for universal application.

The limonite ores are commonly known as residuary iron ores and are supposed by many investigators to represent the insoluble oxidized particles of iron that were originally present in limestones or shales in the form of carbonates or sulphides and were left as a residuum when the mass of the country rock was removed by solution. Such an explanation, however, disregards the concentration of the ores in somewhat veinlike ore bodies. The particles of limonite have not merely been left as a relatively insoluble residuum on the removal of the enclosing rock, but instead, in the main, they have been transported in solution and precipitated in more or less concentrated form in the clays that are plainly of residuary origin. For these reasons the term "residuary limonite ores" is likely to be misleading and is only appropriate if the ores are considered to represent materials that were once distributed through a great thickness of rocks now removed by erosion. The ores themselves have also been dissolved, transported, and precipitated, perhaps several times.

In the discussion of the origin of the brown iron ores, three stages should be considered—the original source of the iron, the primary segregation, and the secondary concentration.

Original source of the iron.—The iron of the brown iron ores probably was present in the form of pyrite, magnetite, or some ferromagnesian silicate, original constituents of the igneous rocks that underlie all the sedimentary strata in which the bodies of ore now occur. When the Cambrian and Ordovician sandstones, limestones, and shales were deposited in the shallow waters of the Appalachian sea both pyrite and siderite were precipitated from solution to form part of these sedimentary strata. Consequently all the rocks of the region—gneisses, sandstones, limestones, and shales—have contributed material for the formation of the ore bodies. Not only have the rocks now present in the region yielded iron for these dposits, but much was also derived from a great thickness of rocks which once overlay the present strata and was removed in the long period during which the Appalachian province has been subjected to erosion. At least 10,000 feet of strata have been removed by erosion from the region since Ordovician time, and though most of the iron of these rocks doubtless was carried away, a considerable portion was dissolved and precipitated in the underlying rocks.

Primary segregation of the iron.—The most striking feature of the occurrence of limonite deposits in the limestones is their relation to channels of underground drainage. The abundance of water was a serious obstacle in the operation of almost every valley-ore mine that was more than fifty feet in depth though elsewhere in the limestone valleys wells must be sunk much deeper in order to procure enough water for household use. As these water channels are formed by the fractures in the rocks that were produced during the great earth disturbances at the ends of the Ordovician and Carboniferous periods, it is reasonably certain that the ground water has been flowing through them for millions of years.

The mountain ores also occur in regions where the rocks have been fractured and afford free circulation of ground water. In every place in the region where the mountain ores have been mined, the Cambrian sandstones and shales have been largely altered to jasper or chert. The metamorphism is believed to have taken place mainly at the end of the Ordovician period, when the region was subjected to intense dynamic forces that resulted in the intricate folding and faulting now so well exhibited. Post-Carboniferous movements also have been effective in producing the complicated structure. Meteoric waters that passed through the deformed strata undoubtedly were heated above normal temperature and their dissolving power was increased. The grains of quartz of the sandstones were dissolved, and the material was later precipitated in the cryptocrystalline form. In the replacement there was a considerable shrinkage, as is shown by the numerous contraction cracks or brecciated form of the jasperoid rock. In some places the cavities were subsequently filled with quartz or jasper which made the rock almost as compact as it was originally, but in general the jasperoid rock is extremely cavernous.

The first step in the formation of the ore was the segregation of the iron that was disseminated through the gneisses, sandstones, limestones, and shales of the region in the form of pyrite and siderite. Meteoric waters that passed downward through the strata dissolved the pyrite and siderite. When these solutions reached the shattered areas in the limestones or the zones of porous jasperoid rock that rested on gneisses the water in many places ascended, just as now the deep-seated waters of the region rise to the surface along fault or fracture zones. Even in the areas where only limestones are present, flowing wells have been obtained at depths of 750 feet, which shows the tendency of the deeper waters of the region to rise under artesian pressure when a passageway is provided.

In the Cambrian sandstones the ascending solutions precipitated pyrite in part as a filling of previous existing cavities and in part as a metasomatic replacement of the jasperoid rock or the shales that were interbedded with the quartzite, especially in the upper part of the formation. So few mines have been worked to the depth where the pyrite ore still persists that little evidence of the manner of deposition of the pyrite is available. Some specimens obtained from one of the mines about halfway between Emmaus and Mountainville indicate an almost complete replacement of the quartzite, but it is doubtful whether these are typical. Instead, it is probable that the substitution of the pyrite for the jasper and shales was irregular and variable. One of the chief supports of the view that ascending waters have caused the segregation of the pyrite is furnished by the depth to which the pyrite extends. It is now found at the greatest depths explored, far below ground-water level. The level of ground water has fallen as the valleys have been deepened by erosion, and therefore it is probable that part of the pyrite was formed at much greater depths than would be possible if it were segregated by descending waters. Besides, in the almost complete absence of any organic matter in the Cambrian quartzite it is difficult to see how the precipitation of the pyrite could have been accomplished by descending waters rich in oxygen, in which the temperature and pressure would have continually been on the increase. Decrease of temperature and relief of pressure were probably the dominant factors in the precipitation of the pyrite from the ascending solutions.

In regard to the valley ores, the primary segregation of pyrite by artesian waters as the first stage in the formation of the present ore bodies is less definitely known. The massive pyrite found in the lower levels of the Friedensville zinc mines and the increase of pyrite with depth in many of the limonite valley-ore mines indicate the presence of pyrite beneath the brown ores in certain places, although the data are too meager to warrant the conclusion that a zone of pyrite is everywhere present. In a brown iron ore mine near Breinigsville enough pyrite was obtained in the lower levels to be profitably marketed. In most places, however, the mines were not worked deep enough to determine whether pyrite commonly underlies the limonite ores or not. The increase of sulphur in the ore caused some mines to become unprofitable, but the excess of water and the slumping of the clay banks were the principal causes for other mines closing before a zone of pyrite was reached. Nevertheless, the facts at hand warrant the conclusion that many of the great limonite deposits of the region are underlain by considerable pyrite, which, however, may be and probably is as a rule too greatly disseminated to be of any economic importance.

Part of the precipitation took place in open fissures in the limestones, but much of it was in the nature of replacement of the rocks that constitute the walls of the fissures. This feature was plainly shown in the Friedensville zinc mines, where the limestones were extensively replaced by pyrite.

The brown iron ores are invariably associated with a large amount of clay representing the residuum of shaly strata interbedded with the limestones and sandstones. These impervious shaly beds undoubtedly, to a large degree, furnished favorable conditions for the primary segregation of the pyrite through assisting the concentrated flow of the mineralized underground waters, and the places where the shaly strata were present were therefore most suitable for the deposition of the minerals that were carried in solution.

The presence of pyrite in the lower workings in considerable quantities seems to indicate that the ores cannot have been formed entirely by descending waters that have brought the iron in solution to these places, as is generally supposed. The abundance of pyrite invalidates the explanation of other writers who believed that the ores were deposited in the Cambro-Ordovician sea as limonites or that they represent the oxidation in place of iron carbonate ores that were deposited as marine precipitates. There are, likewise, valid objections to the explanation proposed by Chance,* who believed that the ores are gossan deposits that were formed by the oxidation of pyrite which was ''a mechanically transported sediment, derived from the erosion of older eruptives.'' On account of the instability of pyrite it could hardly be liberated from igneous rocks through the decomposition of some of the constituent minerals without itself being oxidized, and the situation of most if not all the ore bodies in regions where the rocks have been greatly shattered might also be used as an argument against this view.

Whether the carbonate ores were formed during the primary mineralization cannot be definitely determined without additional information. The carbonate ores are found in the lower levels of both the valley-ore and the mountain-ore mines in association with the limonite, but data are lacking as to their association with the underlying pyrite. Where the ascending iron-bearing solutions came into contact with limestones or encountered carbonate waters from the limestones, it would be natural to expect the formation of siderite, and in all probability part of the iron in the primary segregation was precipitated as siderite and either replaced the rocks or filled fissures just as the pyrite did. In the Wharton mine, southeast of Hellertown, Northampton County, the carbonate ore was less abundant in the lowest workings than it was a short distance above them, which might mean that it did not extend into the region of unaltered primary mineral deposition and thus points to its secondary character. At present it is well to consider the carbonate ores as in part primary and in part secondary, and not to attempt to say which class is the more important.

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* Chance, H. M., Am. Inst. Min. Eng., Trans., vol. 39, pp. 522-539, 1909.

Secondary concentration of the iron ores.—The present workable iron deposits are the products of alteration of the original segregations of pyrite by descending waters carrying oxygen and carbon dioxide in solution. Some of the sulphide was changed directly to limonite, forming a spongy ore characteristic of gossan deposits; other portions were altered to limonite that was taken into solution and metasomatically replaced part of the associated quartzite or was precipitated in open spaces as stalactites of limonite; and still other portions were converted into siderite and precipitated as bombshell ore or compact rounded concretions. Numerous specimens illustrating each of these processes have been found in the vicinity of the abandoned iron mines.

The following chemical reactions illustrate some of the probable changes which took place.

$$FeS_2+7O+H_2O=FeSO_4+H_2SO_4$$
$$6FeSO_4+3O+3H_2O=Fe_2(SO_4)_3+2Fe(OH)_3$$
$$2H_2O+FeSO_4+CaCO_3=FeCO_3+CaSO_4.2H_2O$$
$$FeCO_3+H_2O+CO_2=Fe(HCO_3)_2$$
$$Fe(HCO_3)_2+CaCO_3=FeCO_3+Ca(HCO_3)_2$$
$$2Fe(HCO_3)_2+O+H_2O=Fe(OH)_3+2CO_2$$

In most places the descending waters probably deposited the iron minerals in more concentrated bodies than had been done in the primary mineralization, yet this may not have been true everywhere. In some places where large deposits of pyrite had existed, the mineral waters that resulted from the oxidization and solution of the pyrite probably were dispersed and lost.

As siderite is not stable in the presence of highly oxygenated surface waters, it has practically all been changed to limonite near the surface but still persists a short distance below the ground-water level. In many of the mines, siderite nodules partly altered to limonite can be found.

Pyrolusite occurring with the limonite has had a similar origin. It probably existed in the pyrite and on oxidation was changed to its present form. Part of the manganese has been segregated to form masses of practically pure manganese oxide, but the bulk of it is intimately mixed with the limonite.

In places large rounded masses or small botryoidal segregations of secondary chalcedony are abundant. These masses occur in the clay and may have been formed by ascending waters at the time the pyrite was concentrated or more recently by descending waters. Lack of information regarding their distribution in depth prevents any positive conclusion.

In some of the mines in the limestones there is every indication that the limonite deposits are the result of precipitation from descending waters alone, no pyrite ever having been present in the immediate locality, as the limestone floor gives no indication of the presence of deep fissures through which ascending waters might have brought pyrite. In such places the deposition of the limonite has been produced by percolating waters which dissolved the disseminated iron minerals that were present in the overlying strata and carried them as sulphates or bicarbonates until they were checked in their downward movement by impervious shaly strata or saturated strata and became stagnant and then gradually precipitated the iron in the form of limonite or carbonate, probably by coming into contact with other surface waters that carried oxygen in solution. Such an origin is generally believed to account for most of the limonite deposits that are so widespread in the Appalachian region. According to this theory all limonite deposits would form only close to the surface, and as they could scarcely be expected to form rapidly, the regions where they are found must have been subject to very little erosion for a long period or else the limonite would have been removed by erosion.

During the period of stability in Tertiary time when the Somerville peneplane, so well represented in the limestone valleys, was developed, conditions were favorable for the formation of ore bodies in this manner, and no doubt many of the brown iron ore deposits of the valley-ore type were formed at that time. Similar ore bodies probably were formed during the periods of Harrisburg and Schooley peneplanation, but these deposits have been largely if not entirely removed by subsequent erosion, which has destroyed all portions of these peneplanes in the limestone valleys.

Prime * in his discussion of the iron ores of the region, suggested a secondary origin of a different character for some of the deposits then being worked. He says:

> The whole appearance of the mine is that of a secondary deposit and seems to point to the ore not being in place. All through the yellow clay there are fragments of rock—limestone, damourite slate, and quartzite. The two former are angular, the latter more rounded. The conclusion arrived at by the writer is that the entire deposit has been formed during the Drift period; the ore, rock and clay having been pushed down from deposits to the north or northwest and deposited here in a depression of the limestone rock.

There is no doubt that much of the limonite picked up in the fields owes its present position to transportation by the ice during the glacial epoch but it is extremely doubtful whether any workable deposits have been formed in this manner, as suggested in the passage quoted.

The clay that is associated with the limonite ore represents the residual materials left by the decomposition of aluminous and siliceous strata. These clays were formed at the same time the secondary concentration of the ore took place. In many places shaly laminæ or shale partings are interbedded with the limestones and sandstones, and these strata would yield much clay. Prime believed that the black clays had been formed from some of the overlying Ordovician black slates, which he called Utica slates. In some of the descriptions of individual mines quoted from his report on later pages, statements of this kind are made. The irregular distribution of the black clay and its occurrence in some places in detached masses beneath clays unquestionably formed from strata interbedded with the limestones and

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* Prime, Frederick, Jr., Pennsylvania Second Geol. Survey, Rept. D3, vol. 1, p. 201, 1883.

sandstones preclude such an origin. It must be admitted, however, that the formation of the different kinds of clay—red, white, drab, blue, and black—found in the mines of the region, presents many unsolved problems. Information is lacking in regard to the original character of the beds that gave rise to these varieties of clay. At the surface these strata have been thoroughly decomposed, and there are no deep excavations to furnish the desired data.

The depth to which the clay and the brown ores extend, nearly 200 feet in several places, indicates free underground drainage. Where the rocks have been decomposed to so great depths the structural features, such as the fracture zones previously mentioned, openings between bedding surfaces caused by the uptilting of the strata, and the alteration of limestones and shales or sandstones and shales, favored the collection of the surface waters into channels and produced the localization of weathering described. The depth to which the limonite and the clays extend implies that outlets for subterranean drainage existed at equivalent or lower elevations.

As the decomposition and removal by solution of portions of the strata proceeded, the ground gradually settled downward, producing sink holes, which would still further increase the volume of percolating water through the collection of more of the rain water, which formerly reached the surface streams. When the ice sheet advanced over the limestone valleys these depressed areas were largely obliterated by the deposition of glacial debris, which is generally thicker over the iron-ore deposits than elsewhere.

The settling of the clay owing to the shrinkage of the rocks also broke the particles of iron ore, producing the wash ore described above.

Method of Working

Most of the limonite mines of the limestone region were worked by open cuts, especially in the early stages, and many of the mines of the Cambrian sandstones also were worked in that way. The great quantity of clay and the few ledges of hard rocks associated with the ore at first favored open-cut work, but as the excavations increased in depth the loose materials tended to slide into the pits after heavy rains, and shaft mining replaced the former method. In numerous places shafts have been sunk in or near old pits. Where the mines were on steep slopes, as were many of those in the Cambrian sandstones, the deep cover of hillside wash made shaft mining necessary from the beginning.

In open-cut mining the body of ore, which occurred in a more or less veinlike form, was followed, but mining was not restricted to these bodies. Throughout the mass of clay considerable wash and lump ore would be found, sufficient to justify practically everything being taken out and run through the washers for a considerable distance on both sides of the body of concentrated ore. In this way, in some places, several acres were worked over. When a pit was first opened, horses and carts were used to haul the ore to the washer, but as the mine became deeper, inclined tracks were laid, up which the ore was hauled in small cars. In the open-cut mines of the limestone regions the limestone floor was very irregular. The rock came within twenty-five feet of the surface in many places, but elsewhere it was not reached at the greatest depths. In general, the ore is concentrated to a greater degree where the decomposition of the rocks has proceeded to a great depth, as the ground waters that followed the most open passageways accomplished both the decomposition of the rocks and the segregation of the ore.

In shaft mining the veinlike ore bodies were followed in drifts run at different levels, and stopes were raised to the levels above. Most of these bodies of ore are approximately parallel to the strike of the inclosing rocks, especially in the Hardyston strata, where certain layers were more easily replaced than others. Where the ore that was being followed became lean or disappeared, crosscuts were made to either side, or the direction of the drift was changed in a haphazard manner. In the operation of some mines it was assumed that more ore would be found by drifting in a certain direction, and if this surmise proved incorrect efforts would be made to find ore in another direction. Pockets of good ore were thus likely to be located after several attempts, and at the same time a few lumps and small fragments of ore would be found while driving the exploratory drifts.

The loose clay through which the shafts and drifts were driven may be said, with little exaggeration, to have been in constant motion from the time mining started until all the openings were filled by caving after mining ceased. Shafts were abandoned on account of squeezing, which pushed them out of plumb, and drifts tended to close through the pressure, which at times became so great that large timbers were broken or shoved out of position. In most mines it was necessary to timber both shafts and drifts very carefully, and the close timbering prohibited any examination of the occurrence of the ore except at the working face.

In most mines there were no ore chutes or loading pockets, as the activity of the mines was of too short duration to warrant their construction and also the great amount of clay present would have prevented the ore from running through them. In some mines the ore was loaded in buckets that were placed in a small car, which was then pushed to the bottom of the shaft and hoisted. In other mines small cars were used without the buckets.

The quantity of water encountered was a serious obstacle to the mining in almost every mine that exceeded fifty to seventy-five feet in depth. Cornish pumps were used in almost all the mines, and the water was used in washing the ore.

The mining equipment was never elaborate, because of the character of occurrence of the ore, and the output of any particular mine was consequently small. It is doubtful whether the output of any of the mines averaged more than 35 tons a day, and in most of them the average output was less than half that quantity.

Preparation for Market

The large amount of clay invariably associated with the limonite ore necessitated washing most of the ore before it could be shipped to the furnaces. In some mines masses of fairly pure ore were obtained that were practically free from adhering clay, and these were ready for shipment as mined, but this material was exceptional.

In the washing process several modifications of the common log washer were used. In its simplest form this device is merely a log or shaft to which are attached, in a spiral arrangement, iron plates that project a few inches. This log, which can be rotated, is set at an angle and surrounded by a trough, into which the mixture of ore and clay is dumped. Above the trough runs a water pipe or small trough with numerous perforations through which the water passes to mix with the clay and ore. The ore and the associated clay are dumped into the lower part of the trough, and the log is rotated to carry the large particles upward to the end of the trough, where they fall on a platform, while the water carries the clay in suspension to the lower part, where it flows into wooden troughs, usually supported by trestles, that convey it to a settling pond.

If the clay adheres very firmly to the ore it may become necessary to reverse some of the teeth or plates in the log in order to retard the passage of the ore and give them more opportunity to loosen the clay.

In the washing process pieces of chert or other rocks remain with the ore and must be picked out by hand, and many small fragments of ore are washed away by the water.

Most of the mines yielded enough water for washing the ore, but at times some of them had to obtain additional water from wells or near-by streams. In some places the comparatively clear water from the settling ponds was drawn off into another basin and again pumped to the washers.

The daily average of ore handled by a single washer was never large but ranged from 15 to 35 tons.

Economic Considerations

If a region where iron mining was once one of the principal industries gradually undergoes a change by which all the mines are closed and yet the iron-manufacturing industry still continues, the natural conclusion would be that the iron ore deposits had been exhausted. In Lehigh County, however, where 261 limonite mines are known to have been worked and at present none are in operation, other causes have contributed to the existing situation. Many of the mines were worked out or abandoned because the ore was too lean, but many of them were closed for other reasons, and it is not improbable that as much ore still remains in the ground as has ever been mined. Many of the mines when closed had as much ore in sight as at any preceding period, and undoubtedly there are numerous deposits that were never worked. When the fields are freshly plowed many promising places for prospecting can be distinguished by the brown color of the soil and the fragments of float ore, which favor the conclusion that some ore deposits have never been developed.

In the early days many of the iron companies that operated furnaces acquired ore properties which they either worked or leased under the arrangement that all the ore would be sold to the furnaces at current prices. The royalties paid ranged from twenty to fifty cents a ton. In addition, independent companies acquired ore properties and engaged in iron mining and always found a ready market for their ores. In recent years, however, a great change in the iron industry has resulted in closing most of the small independent furnaces and a concentration of the iron business in a few large companies. The larger companies found so many objections to the local brown iron ores that mining continued to decline until all were closed.

Perhaps the chief objection to the local brown iron ores is the variability of the supply. In winter the severe weather prevented open-cut mines from operating, and the conditions of the roads at times interfered with the delivery of the ore. No concern that uses a large quantity of ore wishes to contract for a supply that is so uncertain.

The variation in composition was also a drawback to the utilization of the local limonite ores. Both the iron content and the amounts of silica and phosporus were extremely variable and hence objectionable. The ore averaged too high in phosphorus for Bessemer ore, and none of it was high in iron. The average limonite ores of the district contained only a little more than 40 percent of iron. Under such conditions it was inevitable that high-grade iron ores low in phosphorus, such as the Lake Superior ores, should replace the local ores when improved transportation facilities permitted competition.

The mine operators also encountered difficulties in the profitable operation of their properties because of the increased cost of labor and the additional cost of pumping the water as the mines became deeper. The result was that many firms hesitated to open new mines when it became necessary to abandon their old ones and decided to disband. Conditions are not now sufficiently favorable to attract new capital to the iron-mining industry.

The future of the mining of brown iron ore in this region is problematic, yet there is reason to believe that at some time mining will be actively resumed, although this will be brought about only by the exhaustion of richer ore deposits of other regions which now supply the local demand. Thus the mining of brown iron ore will not be an important industry in this region for many years, as the Lake Superior, New Jersey, and foreign ores will long continue to replace the local ores. The local operations were necessarily small on account of the manner of occurrence of the ore and so could not compete with operations in those regions where mining can be done on a very extensive scale.

Descriptions of Individual Limonite Iron Mines*

By Albert J. Getz

All of the iron mines of the county have long been closed and very little information can be obtained by visiting the localities. On the dumps and in the mud-dam deposits, one can see the character of the matrix, generally vari-colored clays, and occasional pieces of ore and associated rocks. In a few places the wall rocks are visible. Around most of the limonite ore mines in the Hardyston formation are numerous fragments, or even large masses, of taffy-yellow or brown ferruginous jasper or jasperoid.

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* The quoted descriptions are from Prime's published reports of 1875, 1878, and 1883, and McCreath's reports of 1875, 1879 and 1881. In 1938-39 Mr. Getz made extensive field investigations and the additional descriptions are by him, but supplemented by material supplied by B. L. Miller.

In view of the frequent requests for information concerning individual mines, such data as could be secured is here given. Most of the mines were in operation when Prof. Frederick Prime worked in the region during the field seasons of 1874-1878 and in his reports he gave brief descriptions of certain mines. These are quoted here, together with occasional additional notes by the authors. Numerous objections might be offered to some of Prof. Prime's statements but they are quoted as published. He commonly refers to the jasperoid rock associated with ''mountain ores'' as ''flint'' and also speaks about ''Utica'' shales as being the source of the black clays. Likewise he uses the term ''Potsdam'' for what we now term ''Hardyston'' and calls sericite, ''damourite.'' He also believed that all the limonite ore bodies had been formed in the limestones.

The numbers refer to numbered mines on the map. Lack of descriptions of certain mines is explained by complete lack of worthwhile information. With a few exceptions the mines are numbered consecutively from north to south on the Allentown West and Boyertown quadranges and from west to east on the Allentown quadrangle. The ore from many of the mines was analyzed. These are brought together on a later page and therefore omitted from the descriptions.

In the descriptions of the individual mines there is bound to be much repetition because of similarities. However, the reading of all of these cannot fail to show many variations and the presence of many features not mentioned in the foregoing general descriptions. Each of the mines described was visited. Naturally the present appearances do not reveal many characteristics which Prime was able to see when he made his investigations in the 1870s.

1. P. Steckle's mine east of Ironton.

"At this point there are three abandoned excavations. On the south side of the most western one there is a large bank of Hudson River slate (No. III) and a small quantity of black slate (Utica shale) on the dump. While in the middle pit, there is a small quantity of black and red clay on the north side of the mine, and slate (No. III) occurs in some parts of the sides. The eastern excavation was too full of water to permit of any examination. The sides were much washed, but from what could be seen it would appear as if the ore were surface ore in gravel overlying the Utica shale and possibly over a portion of No. III slate. The reason for this supposition is that blue and black clay (Utica shale) has been struck half way down shafts sunk in the middle pit, and little or no ore was found below this. There is no doubt a good deal of ore still remaining, but too little concentrated and too widely distributed through the deposit to pay for working it."

The three excavations are partly filled with water and the sides covered by trees and brush. Several small dumps are on the northern side of the most easterly excavation. Some quartz, limestone fragments and ore of the lump and fragmental variety may be found.

2. Daniel Steckle's mine.

"The ore formerly went to the Lehigh Valley Iron Co. There are here two abandoned excavations. In the eastern pit the ore occurs in gravel and there seems to be but little of it, although it is said there is considerable ore left, but in such thin streaks as not to pay for working it, nor of sufficient quantity to justify the erection of good machinery."

The mine has since been filled in and only a small dump remains.

3. J. Ritter's mine.

"Leased by the Crane Iron Co. This pit, while close to No. 185 (4), is apparently cut off from it by limestone, and seems therefore to be more closely connected with the mines to the east than those lying to the west. There is an abundance of black clay (decomposed Utica shale) in the southern portion, which lies directly under the sod on the south side, and a little deeper on the north side. Immediately underneath and, to the east, alongside of this, is an abundance of pinkish and white clay; the pink lying almost entirely under the black, the white more alongside, but also underneath it. The line of demarcation between the black and other clays, is sharply defined by the change of color. While their composition is approximately the same, they do not seem to be altogether conformable, for the black clay has a northwest dip, while the white has a southwest one. Still these dips are not conclusive, since the clays may have been crimpled and folded by the erosion of the limestone underneath them.

"The comparative age of these clays, is, however, of considerable importance as bearing on the origin of the brown hematite ores, as there is a bed of this 8 to 13 inches thick, which cuts through both the black and the white clays. If now these two clays, or the rocks from which they were formed by decomposition, are of the same age, this bed of ore may have been formed cotemporaneously with the enclosing rocks; but if they are of different ages, then, of course, the ore must have been formed by subsequent deposition. The mine, when last visited, was being worked into a good condition, and promised to yield a good deal of ore, the openings in the bottom of the mine being favorable, although the amount in sight was not very large."

The Ritter mine is almost completely filled with water. The banks are somewhat grass-grown but show evidence of yellow clay. Quartz, limestone fragments, and lump and fragmental ore are to be found. A dump at the northeast end of mine offers best specimens. Several small dumps are at the northeast and eastern ends of the mine.

4. P. Brown's mine.

"This pit is but a short distance from the last; it is about 70 feet deep. The mine lies directly in the centre of the limestone synclinal mentioned under mine No. 182 (7), and it is very probable that the ore continues from it to mine No. 184 (5). When last visited work had been stopped and the mine allowed to fill with water owing to a difficulty in selling the ore at a remunerative price during the present period of depression in the iron business. When first visited there was a very good breast of ore some 30 or 40 feet thick in the west end of the excavation, the breast consisting almost entirely of pure ore intermingled with damourite slate and clay and more or less allophane. The eastern end is composed of white clay resulting from the decomposition of damourite slate; but it is a subsequent deposit, for that portion of it on which the plane rests and just north of it, shows from the carbonized wood which has been converted to lignite and from the remains of leaves and a small beech-nut (all of which have been found in it) that this portion at least of the clay is of Post-Tertiary age. The superior position of the clay, stratigraphically, to the ore shows the former to be younger than the latter. The mine presents a very favorable appearance in its western portion. Overlying the ore is black clay (decomposed Utica shale), being thickest in its northern portion, that on the south side having been eroded. Overlying this is a little surface soil. The future of this mine is apparently more favorable than those just described, for while there is but little prospect of ore being found to the east, where the limestone cuts it off, or to the south, where it must soon crop out, it is very likely that a good deal of it will be found in the interval of virgin ground between this mine and No. 184 (5). To the northeast trial pits have been sunk, but with no very favorable indications, nor could any other result have been expected, owing to the proximity of the shafts to the limestone."

Characteristics of this mine are typical of those of mines 5, 6, and 7.

5. Balliet Heirs' mine.
6. Balliet Brothers' mine.
7. Ironton Railroad Co.'s mine.

"These three mines form but one excavation (pl. 25, C), being however separate properties. Taken together they form the largest mine in Lehigh County and more ore has been taken from it than any other. The mine has been worked for forty years, and ore is said to have projected above the surface of the ground before the deposit was opened. The mine is now 2,000 feet long and 800 feet broad and is 90 feet deep at the lowest point. Limestone can be seen at various points, occurring in such a manner as to be nearer the surface at the eastern portion of the excavation and deepening towards the western end. The sides of the excavation consist for the most part of a plastic clay, formed by the decomposition of damourite slate. The greater portion of this is colored yellow by ferric oxide, but a good deal of it is white, while other portions are colored pink to red by an oxide of mangagnese. In addition to this, black clay(decomposed Utica shale) occurs in various portions of the mine, notably at the northwest end, in the centre, and at the eastern extremity. These different portions once formed a continuous bed, which has been removed in mining the ore. This black clay contains a very curious looking, nodular and concretionary iron ore, much resembling that met with at times in the slates of the coal measures and which is an argillaceous carbonate of iron, known as clay iron-stone. Its quantity is too small and it is too irregularly distributed to render it an object of exploitation. Of more interest to the mineralogist is the occurrence of native copper in this black clay, which is found in small filiform pieces. Its presence in the metallic state being probably due to the carbonaceous matter in the clay. The black clay varies from 1 to 10 feet in thickness, being occasionally as great as 20 feet. The only reason for supposing it to be decomposed Utica shale is its geological position and the fact that it contains graphite.

"Ore occurs in various parts of the mine, the greater portion of it below the black clay, especially at the west end close to the Ballietsville road, in the lowest portion of the mine near its centre, and along the northern side of the central portion.

"Black oxide of manganese (psilomelane) has been twice met with in considerable quantities, in both cases forming local beds. Once, three years ago, in a deposit over a portion of the brown hematite, from which a good many tons were taken, and more recently (1875) in the deepest portion of the mine, just above the limestone. The deposit has been exhausted since it was visited, several hundred tons having been taken from it. This last bed laid under the brown hematite ore, being separated from it by a red clay, and its presence in this position is most probably due to the greater solubility of the salts of manganese compared to those of iron.

"Limestone has been met with in place at various points in the bottom of the mine. Along the southern central portion of the pit the limestone has a northwest and west dip, while that which occurs in the eastern portion of the northern half has a southeast dip. These dips, taken in connection with the southeast dips on the Ballietsville road north of the mine and the limestone synclinal, separating the Ritter's Mine, No. 186 (3), from the others, show a synclinal structure. The limestone has been met with much nearer the surface in the eastern portion of the excavation than in the western, and consequently much more ore has been taken out of the latter than the former. The synclinal structure and the fact that limestone has been struck in place in the deepest portion of that part of the mine belonging to the Ironton Railroad Co., leaves little, if any, ground of hope that much more can be met with there. West of that part where the manganese ore was met with, the limestone probably goes deeper, and it may be that ore will be found to a depth of thirty feet or more before meeting the limestone. There is every evidence however that the mine is approaching exhaustion, unless ore should be found west of the Ballietsville road. Even in such a case it is scarcely probable that any great quantity of it will be found, as the slate will probably intervene and cut it off; the dividing line between the slate and the limestone, as drawn on the map, being only approximate, the actual line of contact being concealed. The reason for supposing that the overlying slate will cut off the underlying ore, is that at no point hitherto has the ore been followed under the slate."

Mine 5. Consists of two excavations. The smaller of the two and southwest of the larger was the first opening of the mine. Overnight it was flooded out, later pumped dry, and then again it flooded. At times when beds of pyritic material were encountered in the tunnels, the sulphur fumes are said to have been very strong. It is separated from the larger pit by a yellow and white clay bank containing pyritic material. Quartz containing some limonitic material, limestone fragments, and lump and fragmental ore are found here. Some of the lump ore has a distinct honeycomb structure. The water in this pit is dark blue or almost black. The banks of this pit are grass-grown and the pit is surrounded by dumps of all sizes, most of which are covered by grass and brush. The sides of the larger pit of this mine are mostly covered by grass and brush, only a few sections of the banks being exposed. This pit also is surrounded by dumps of all sizes. A dolomitic limestone crops out on the southern bank. As contrasted with the water of the smaller pit, the water is deep green and almost fills the pit.

Mine 6. This pit is almost filled with water and is separated from mine 5 and mine 7 by banks of earth, which are for the most part made up of yellow and white clay and pyritic material. The water is a deep green color. The banks are grass-grown and covered by brush. Limestone fragments and also quartz containing limonitic material are found in fairly large amounts. Lump ore having a honeycomb structure and fragmental ore are abundant.

Mine 7. This pit is filled with water and the banks are covered by grass and brush. There is a small island of yellow clay at the northwestern end of the pit. Dumps of all sizes, mostly grass-grown, surround the pit. Pyritic material and yellow and white clay compose most of the larger dumps. Limestone is in place at the eastern end of the pit. Limestone fragments, quartz, and sericitic material are abundant. Most of the ore is lump and fragmental.

8. J. Baer's mine.

"Leased by .... Woodring. Not being worked. The sides are much washed. The ore appears to occur in gravel and surface soil."

The pit has been filled in, but some fragments of ore may be found in the vicinity of what at one time was the pit.

9. H. Mickley's mine.

"This mine is abandoned and full of water. There is a little island in the centre, composed in great part of white hydromica clay, which can also be seen at one or two points on the northwest side of the pit. Black clay (Utica shale) occurs on the northwest side close to the water's edge. There is no ore in sight above water level, and the mine is said to be exhausted."

The pit is filled with water, but a small section of the north bank shows yellow clay and some pyritic material. Some quartz and fragmental ore are present. A small dump is present south of pit and about 200 feet from the road running along the southern edge of the pit. At the southeastern end of the pit the road cuts through a dump exposing yellow clay, pyritic material, some quartz, and sericitic material.

10. Ironton Railroad Co.'s mine.

"The greater part of the excavation is occupied by yellow plastic clay, white (hydromica) clay occurring in the centre and northern part of it. A little black clay (decomposed Utica shale) is seen in the northeast and northern part of the pit, overlying the white clay. But very little ore could be seen in the mine when visited, and that was to the northwest of and in direct contact with the black clay, but underneath this."

The pit is almost filled with water. A large dump at the northwestern end of the pit and several smaller dumps contain considerable pyritic material. Lump ore is abundant, as is quartz containing some limonitic and sericitic material. Yellow and white clay make up most of the dumps. Very little limestone is to be found. Some of the pyritic material gives off a slightly sulphurous odor when broken.

11. Thomas Schadt's mine.

"In the north opening, which is 20 feet to the water, there is a little drift ore on the top. Then succeeds a heavy body of damourite slate, containing a few lean lumps of ore. At the south end there is a bed of ore about 4 feet thick, which passes under a road between the two openings. At the south pit, which is 40 feet deep, there is little or no ore in sight; here the damourite slate is decomposed to a sandy condition. It is said that there is a little ore under the mud dam. There is not a sufficient quantity of ore to justify working it."

The pit is now completely covered by trees and brush.

12. M. Schadt's mine.

"In this mine, but recently opened, the ore consists of lump and wash-ore in surface clay mixed with much flint. But little could be seen. A well was sunk 106 feet for water, and although in limestone at that depth, the supply was insufficient. Consequently a drill-hole was being sunk when the mine was visited, and at a depth of 196 feet from the surface an ample supply was met with. The drill-hole went through limestone alternating with thin seams of clay, but no record had been kept of the rock passed through."

This pit is now completely covered by trees, grass, and brush.

13. D. Ruch's mine.

"In the northeast corner of the pit a single bed of ore is apparent, but it is being covered up by throwing in surface soil, so that it could not have paid. A new opening has been very recently begun, and the surface soil also yields a certain amount of ore."

This pit is now completely filled.

14, 16. J. Scheirer's mines.

"No. 172 (16) is abandoned and consists of two pits divided by the road, that to the west being much the largest. The ore here formed merely a pocket in the gravel, and was not in place; it has long since been worked out. At No. 173 (14) the mine is new and the ore thus far mined has been chiefly in surface drift and stripping, most of it being red or partly anhydrous ore. In the excavation they have just reached the top of the ore in place. In some of the trial-pits around the mine, lump-ore was found in an abundance of white clay. The mine has been too recently opened to give any opinions as to its character. From the discoveries made in the trial pits, it seems to promise well."

Both pits are completely covered by trees, brush, and grass so that there is very little to be seen.

15. Charles Ritter's mine.

"The mine is abandoned and full of water, while the sides are grass-grown. It has not been worked for some time. The ore was only surface ore in gravel."

This pit is completely covered by trees, brush, and grass.

17. This is a fairly large mine hole partly filled with water. The sides are covered by trees and brush. Exposed sections of the banks show yellow clay, limestone fragments, a little lump ore, and some quartz.

18. Jonas Biery's mine.

"The mine has not been worked for some time and the sides are much washed. The ore was taken out from between beds of limestone, which dips south about 20°. On the north side white clay (decomposed damourite slate) occurs above the limestone. The ore which remained on the dump was very light, being probably the poorest which had been mined and left behind. The mine does not present a favorable appearance, and probably very little ore remains to be taken out."

This pit is on the property of the Trojan Powder Co. and is covered by trees and brush. A small section of it has been filled in by ash. There is a large amount of pipe and stalactitic ore in the bottom of the pit. Limestone is in place on the east and northeast sides of the pit. An old shaft at the south end has been filled in. Some quartz and yellow clay are also present.

19. William Roth's mine.

"The ore from this small excavation is entirely pipe ore, which is extracted from between broken beds of limestone, and which has been formed as stalactites by the water percolating through the limestone. Neither bombshell nor wash ore is found. The ore found is comparatively little in amount. It is taken to the Lehigh Valley Iron Works."

This pit is now completely covered by thick woods and brush.

20. Ephraim Wenner's mine.

"The mine is not worked and the sides are too much washed to see how much ore remains in the pit. Damourite slate and white clay can be seen in the west end, which dip under limestone in the south side. The limestone has the same dip as that near it along Jordan Creek."

This is a small pit partly filled with water. Limestone crops out on the southwest end of the pit. Several small dumps on the east edge of the pit are partly covered with grass and trees; and here occur quartz with some limonitic material, limestone fragments, sericitic material, and ore of the lump and fragmental varieties.

21. P. Marck's mine.

"Leased by the Lehigh Valley Iron Co. It is full of water and not worked and nothing can be seen. On the dumps of some shafts sunk close to this mine damourite slate could be seen, which is of a pinkish color; as well as a black slaty rock, which is probably Utica shale. White clay was also present."

This is a fairly large pit filled with water. The banks are covered with trees and brush. Exposed sections of the bank show some quartz, sericitic material, limestone fragments, and lump and fragmental ore.

22. John Scherer's mine.

"The mine is not worked at present, whether from exhaustion of the ore or on account of the hard times could not be definitely ascertained. The sides are much washed and there is no ore in sight. At the west end of the mine there is a little white clay near the top. In the middle of the excavation a shaft has been sunk, now filled up, from which a black earth and a brown slate has been taken. The latter is probably Utica shale."

This pit is completely covered by trees and brush.

23. Barber and Ainey's mine.

"This mine was not working when visited. It showed both lump and wash ore of good quality. On the west side there is a heavy body of white clay; while on the east side there is a small body of the same, which is replaced below by ore and yellow clay. The sides are much washed and showed pieces of No. III slate, which could not be found in place. As the bottom of the mine was full of water it was inaccessible."

This is a large mine hole with the bottom covered by water, and the banks partly covered by trees, brush, and grass. Exposed sections of the banks show red, yellow, and white clay, some quartz, a few limestone fragments, and considerable sericitic material. Some lump ore also is present.

24, 25. Jobst's mines.

"These pits have not been worked for some years and only gravel can be seen on their sides; there is a little damourite slate on the old dump. To the south and east of No. 156 (24) trial shafts have been sunk in white clay, but with apparently little success as to ore."

24 is a small pit covered by grass and brush and being filled in. Nothing can be seen. 25 has been filled in.

26. J. Kartzer's mine.

"This excavation is not worked, and is apparently abandoned. But little ore has been taken out, and the sides are so washed it is impossible to see anything. The ore is apparently in Drift or a mere superficial deposit."

This pit has been filled in.

27. A very small pit covered and filled by trees and brush. There is very little to be seen here with the exception of a little lump ore, some quartz, and a few limestone fragments.

28. This pit is several hundred feet long and about 65 feet deep. The banks and bottom are grass-grown. A small bank of yellow clay projects into the pit. Limestone blocks are numerous on a dump at one side. Lump ore is present, and the fragmental ore has the appearance of having been bombshell ore. Flint, quartz, siliceous materials, and some sericitic material are present.

29. John Henninger's mine.

"This mine was standing idle when first visited, but had just commenced to be worked again when last seen. The most southern of the two excavations was full of water, and nothing to be seen. In the northern pit, ore was in sight in the very bottom, but the sides were so washed, that little could be seen, except a little white clay. To the north of the inclined plane, and close to it, at the surface, there is gray clay mixed with leaves, &c., which are decomposed, belonging to the Drift Period. This is about 5 feet thick, and above it are about 4 feet of yellow clay."

Three of the four excavations here are filled with water and are connected by a stream. The smallest of these three pits is separated from the middle and largest pit by a small clay bank. The two nearest the road and railroad are rather large and do not show much. The fourth pit is about 50 feet north of the other three, is long and narrow, and only a few feet deep. The sides of this mine are made up largely of yellow and white clay. Several large dumps northwest of the three larger pits are also largely composed of yellow and white clay. Quartz and flint occur in fairly large amounts on the dumps. Some limestone fragments and considerable sericitic material are present. The ore is lump and fragmental.

30. Daniel Levan's mine.

"This mine is in the same condition as mine No. 164 (32). Wash ore; arenaceous, cellular; cells carrying considerable clay."

This is a rather large pit filled with water almost to the top of the banks. The exposed sections of the bank show some quartz containing limonitic material, sericitic material, and lump and fragmental ore. Some limestone fragments may also be found here. At the southwest end of the mine hole there is a large dump almost completely covered by grass.

31. This large shallow pit adjacent to mine 30 and a large dump at the north end are covered by trees and brush. Some lump ore and quartz containing limonitic material are found here.

32. A. Balliet's mine.

"Not worked, and apparently abandoned. The sides so washed, it is impossible to see anything."

Three small pits make up this mine. Two are covered by trees and brush, and the other is only a small depression. Nothing is to be seen here.

33. Crane Iron Co.'s mine.

"This pit is not worked, and is apparently abandoned. A little white clay can be seen in the center close to the water in the bottom. The south end is said to still contain ore, but the sides are grass-grown, so that it is impossible to see anything."

"Near this the Crane Iron Co. have leased the ore-right on Thomas Bleiler's farm. It had not been opened when visited, but the trial-shafts sunk indicated a rich and considerable deposit of ore."

This is a large pit partly filled with water and the sides covered with trees and brush. A rock pile at one end of the pit contains considerable glacial material and a few lumps of ore. Quartz and limestone fragments and a little sericitic material are present. Yellow clay is exposed in one of the sides.

34. Daniel Gackenbach's mine.

"This is not worked, and is apparently abandoned. The sides were so much washed it was impossible to see anything of the nature of the deposit."

This is a large pit, grass-grown and bearing a few trees. Limestone, quartz with some limonitic material in it, lump and fragmental ore, and some sericitic material are present. Limestone is in place on the southern bank. Yellow clay is abundant.

35. Hiram Boyer's mine.

"Leased by the Lehigh Valley Iron Co. The surface soil varies from 1 to 30 feet in thickness, and contains a sufficient amount of ore to pay for washing it. The ore occurs chiefly in yellow and white clay, the latter coming in places to within a foot of the surface. At one spot there is a bed of ore about a foot thick. The mine when visited did not present a favorable appearance, except at a few points. Nearly all the ore is wash ore, but little lump ore being obtained."

"Wash ore; cellular, stalactitic, and argillaceous."

This large pit is about 100 feet deep. Most of the hole is grass-grown and covered with trees, but there are bare spots on the south wall of the pit. Several small dumps on the north side show considerable quartz in fragments and large blocks up to two feet in diameter containing some limonitic material. Lump and fragmental ore is also found here. Limestone occurs in place on a small earthen bench that runs along the north side of the mine. Yellow clay occurs on the sides of the pit.

36. Two small pits partly filled with water and surrounded by trees and brush. Here are some large blocks and a few fragments of quartz, some siliceous material, limestone fragments, and a little lump ore. Yellow clay occurs on some of the banks. At the one end of the two pits there is a small dump covered with brush and grass.

37. Daniel Henry's mine.

"Also not worked, and in the same condition as (38)."

A small pit, rather deep, is at the edge of a wood. The bottom is filled with water, and the sides are grass-grown and covered with trees, so that nothing can be seen.

38. Horace Guth's mine.

"This mine was not being worked, and the sides were too much washed to see anything."

This pit is partly filled with water and its sides are grass-grown and covered with trees. Yellow clay is exposed on one of the banks, but other than that there is nothing to be seen.

39. Richard Blank's mine.

"Long since abandoned. It is full of water and grass grown."

This is a small pit covered by trees and brush. There is nothing to be seen.

40. Calvin Guth's mine.

"Leased by the Bethlehem Iron Co. This pit, which is about 50 feet deep, looks well in the south end, the ore forming strings, more or less thick, in decomposed damourite slate. Both lump and wash ore is obtained. Two wells have been sunk in search of water for the washer; one, about 65 feet deep, struck limestone; the other, about 170 feet deep, did not strike rock at all. Thus showing that the rock below has been more or less decomposed. The sides are much washed, so that is was impossible to obtain any satisfactory dip."

"Ore is arenaceous and cellular; some of the pieces fine-grained and flaggy. Color is various shades of brown and vermillion."

This pit is almost completely covered by trees and brush except on the south side. A large mound of yellow clay in the middle of the pit probably is the remnant of a former dump. Quartz, flint, limestone fragments, and considerable sericitic material are on the dump. Lump and fragmental ore is abundant.

41. Wenner's mine.

"Abandoned and the sides washed. No damourite slate or white clay could be seen. In the north end there is a little limestone, apparently in place."

This small pit is partly filled with water and surrounded by trees and brush. A little yellow clay is to be seen here, some quartz, and a few limestone fragments.

42. Wenner's mine.

"Abandoned and full of water."

This is a large pit partly filled with water. Grass and brush cover the sides. Yellow and white clay are present on a small dump in one end of the pit. Quartz, flint, sericitic material, and lump and fragmental ore are present.

43. Crane Iron Co.'s mine.

"Abandoned and full of water. On the dump there is damourite slate and white clay."

This mine is filled with water. Where the sides are not completely covered, some yellow clay is exposed and here we find quartz containing limonitic material, limestone fragments, sericitic material, and a little ore.

44. D. A. Guth's mine.

"The mine is not working, the bottom is full of water and the sides are so washed that but little could be seen. On the north side there is a body of white clay. In one portion of the mine there is a black pigment and slate, the latter probably belonging to the Utica shale. This apparently passes under the limestone and white clay which are present. The limestone has a southeast dip, while the Utica shale seems to dip to the northwest, both of them variable in amount."

This pit adjoins Mine 45 and is separated from it only by a small wall of clay and earth . A dump shows evidence of pyrite having been present. Limestone is in place on the northwest side of the pit. Quartz, limestone fragments, sericitic material, and lump and fragmental ore are also present.

45. Thomas Iron Co.'s mine.

"This pit is abandoned and grass-grown. The ore was associated with white clay; the limestone to the southeast must have laid over it."

This large pit is filled with water. Limestone in large outcrops on the southeast side of the pit is somewhat siliceous and has a conglomeratic phase. Sericitic material, ore fragments, quartz, flint, and limestone fragments are also present.

46. Thomas Iron Co.'s mine.

"This mine is in the same condition as the last (45). From the refuse on the dump it is evident that the ore must have occurred in damourite slate."

This pit is surrounded and filled with trees and brush.

47. James Kline's mine.

"Leased by the Thomas Iron Co. The greatest portion of the ore has been extracted and the mud from the washer is being run into the excavation, ore only being taken out of the northeast corner. At this point the surface soil is about 20 feet deep, then about 10 feet of red clay containing ore, underneath which are yellow and white clay containing streaks of ore. But little lump ore is found. In many places the damourite adheres closely to the ore, so that it cannot be separated by washing. White clay occurs above the ore, as well as under it. In the west end the surface soil is about 14 feet deep, under which occurs a heavy body of white clay, which continues down to the water in the bottom. There is a good deal of disintegrated damourite slate associated with the clay. There is no ore in sight in this portion of the mine, which is now abandoned. A great deal of ore has been taken out of this mine, which only looks well at one small point where it is now being mined."

"Lump and wash ore. Compact, flaggy, and arenaceous; considerable yellow, white, and pink-tinted clay.

This pit is several thousand feet long and divided into three smaller pits by banks of yellow clay. The most westerly pit is filled with dark green water which contains so much sulphur that animals cannot live in it. The large dumps surrounding the pit contain considerable clayey pyritic material as well as fragmental, lump, pipe, and bombshell ore, considerable sericitic material, some limestone, and a little limonitic quartz.

48. Benjamin Weaver's mine.

"Leased by the Coleraine Iron Co. This pit is now 40 feet deep; it is said that most of the ore occurs about 15 feet below the present bottom of the mine. Near the top there is damourite slate which is underlaid by white clay containing ore. At the north end there is damourite slate in which thin seams or strings of ore occur, but the great bulk of the ore is underneath it. The slate looks very much like the No. III slate."

"Lump and wash ore. Compact, and brittle; dark brown. Fine ore carries considerable quartz."

This mine is completely filled in.

49. J. Reinhart's mine.

"Leased by the Allentown Rolling Mill Co. This pit is not 10 feet deep. The ore is for the most part lump and occurs in yellow clay, not resulting from the decomposition of damourite slate; at the east end the ore is apparently de-hydrated. The mine is not worked and the sides are washed which makes it impossible to ascertain the character of the deposit."

This mine has been filled in.

50. This large pit northwest of mine 33 is rimmed by trees and brush and filled with water. Lump ore and limestone crop out where a small brook runs into the mine.

51. Samuel Sieger's mine.

"Leased by the Bethlehem Iron Co. This mine was only being worked at its east end. At this point there is a thin covering of surface soil, under which is a vein about 6 inches thick in white and yellow clay. There is then an interval of 12 feet without any ore, below which there is a bed of the latter 2 to 4 feet thick. It was stated at the mine that a shaft in the bottom had been sunk 40 feet all the way in ore. A good deal of lump ore is found near the surface, and the clay in places is of a blood-red color. At one point there is limestone above the clay, the former thoroughly permeated by damourite."

"Lump and wash ore. Arenaceous and cellular with the cells much filled with clay. Some of the ore is compact and fine-grained with a flaggy structure. Wash ore carries considerable quartz."

This pit is about 100 feet deep and contains about 5 feet of water. Brush and trees cover most of the sides. Yellow clay is present in rather large amounts. Fragmental and bombshell ore, limestone fragments, and quartz containing limonitic material are abundant. Limestone crops out on the north bank of the pit.

52. This is a very small and shallow pit containing some yellow clay, quartz, and a few fragments of ore and limestone.

53. Kræmlich and Lichtenwallner's mine.

"Leased by the Crane Iron Co. This mine, which is 50 feet deep, has not been worked since the Fall of 1873. A blue water-worn limestone occurs in the bottom of the excavation, whose stratification is apparently horizontal. There is evidently a large quantity of damourite-slate and white clay underlying the ore, and in some places in it. Pieces of sharp, angular quartz are common in the clay on the slope of the mine."

"Limonite, hard and cellular; the pieces being generally of a slaty structure; the color of the ore is a dark brown and a cinnamon brown."

This pit is partly filled with water and its sides are covered by trees and brush. Limestone cropping out on the north and southwest sides has a slaty appearance and cleavage. Ore and quartz are rare.

54. Levi Lichtenwallner's mine.

"Leased by the Crane Iron Co. At this mine there are several excavations. The most southerly one is full of water at the bottom, and is 26 feet deep to the water. There is a plane in this pit. The small one to the north of this is only 10 feet deep; only stripping having been taken from it. The largest excavation of all lies still more to the north; this is 40 feet deep, and is no longer worked. To the west of this is a small pit 15 feet deep. The mine has not been worked since the Fall of 1873. The ore occurs in white clay, and overlying damourite-slate. In some places the clay apparently overlies the ore, but clay or slate underlies it. It is said that the well, which has been sunk to a considerable distance, struck blue slaty limestone at a depth of 130 feet."

"Limonite, hard and sandy with considerable ocherous iron ore."

This mine has been completely filled in.

55. Jesse Laros's mine.

"Leased by the Crane Iron Co. The ore, from the fragments on the side of the mine, must have been associated with damourite slate."

"Limonite, compact, arenaceous, and of a very dark color."

This pit is filled with water and the sides are grass-grown. A little yellow clay is present, considerable quartz, some of which contains limonitic material, some lump ore, and a few fragments of limestone.

56. Jesse Laros's mine.

"Leased by the Crane Iron Co. The depth of the mine to water is 38 feet. On the west side of the mine there is a mixture of clay, quartz, and damourite-slate, all in very small pieces, for a depth of 17 feet from the surface. The ore where visible, at a few points, occurs in clay."

This pit, almost circular, is partly filled with water. High dumps surround most of the pit. Yellow clay, large quantities of quartz, some of which contains limonitic material, limestone fragments, and considerable fragmental ore are to be found here. From the size of the pit and the number of dumps it is evident that a large amount of ore was removed.

57. Henry Stein's mine.

"Abandoned. The mine is 10 to 12 feet deep to water-level. It has not been worked for some time, and nothing can be seen. From the large quantity of clay that has been removed, it is evident that a great deal of ore has been taken out.

This is a large pit filled with water and the sides covered for the most part by trees and brush. Considerable yellow clay, some limestone fragments, and quartz occur here. The ore is chiefly turgite, which is found on the dump at the south end of the pit; a little lump limonite ore is present.

58. Henry Stein's mine.

"Leased by Thomas Iron Co. In this mine no damourite slate was apparent, but the ore occurs in and over white and pink clay, resulting from the decomposition of the slate. The mine is 47 feet deep. At a depth of 40 feet limestone was struck in one portion of the mine which dips 12° S. 41° E. The top limestone is slaty and drab colored. It is 4 feet thick and overlies the ordinary blue waterworn limestone. The clay overlying the limestone and containing the ore, dips 42° in the same direction. In the limestone at the bottom of the mine there is an aperture about 10 inches square into which all the water of the mine pours and disappearing avoids the necessity of any pump to keep the mine dry."

This pit is flooded to within 5 feet of the top. Yellow clay and very little lump ore are present. Quartz occurs in fair amounts and fills some of the abundant fissures and joints in the limestone.

59. Moyer's mine.

"Leased by the Thomas Iron Co. This mine has been very recently opened, being but 6 feet deep, and as yet the ore is nothing but stripping in gravel."

This mine has been completely filled.

60. Jacob Steininger's mine.

"This mine which has not been worked for a long time, is now exhausted, but has yielded a great deal of ore. It is about 600 feet long and 15 to 20 feet deep to the water in it. The banks have been so much washed that it is impossible to see anything on them."

This large pit, partly filled with water, has yellow clay on the banks, very little ore, some quartz, and the west side contains considerable limestone fragments.

61. Jacob Steininger's mine.

"Leased by James Lanigan. This mine is 25 feet deep. The brown hematite occurs in damourite slate and overlying the white clay resulting from the decomposition of the slate. The ore and slate dip 22° to 40° S.40°E. At the bottom of the mine at the north end there occur 12 feet of solid white clay with a thin streak of ore underneath. In the bottom of the excavation a shaft has been sunk to the depth of 18 feet, but no ore was found at a greater depth than 6 feet. The shaft then passed into clay."

"Limonite, compact and arenaceous with considerable admixture of ferruginous clay."

This is a small pit filled with water and the sides grass-grown. There is very little ore, some quartz, and limestone. Considerable clay, very yellow near the mine, becomes darker with distance.

62. Charles Miller's mine.

"Abandoned, and is full of water. . . . The ore occurred irregularly stratified (with damourite slate?) and was covered by slaty debris to a depth of 5 to 25 feet. . . . As the bed sank from the surface along the dip the ore became more solid; but in places the ore was replaced by bodies of clay (from the decomposition of damourite slate?)."

"Limonite, arenaceous and with a large admixture of ocherous iron ore."

This small pit just opposite mine 61 is filled with water and the sides are covered with grass and brush. There is yellow clay here, a little ore, and some quartz which contains limonitic material.

63. This is a very shallow pit which shows only a little yellow clay, some limestone fragments, and a few pieces of lump ore.

64. Charles Miller's mine.

"This is nothing but stripping the surface clay and ore to a depth of 2 to 4 feet."

This large pit is filled with water to within a few feet of the top. Considerable quartz and yellow clay is present. A small dump north of the pit is composed largely of yellow clay partly weathered to a cream color. On this dump there is considerable lump and fragmental ore of the limonite variety, some pieces of turgite, quartz pebbles, and red, brown, and yellow clay.

65. J. D. Scholl & Co.'s mine.

"Leased by the Lehigh Valley Iron Co. The ore occurs very irregularly bedded in white clay, resulting from the decomposition of the damourite slate. There are quite large rolls in the bedding; so that while the general average dip is 10° S.50°E., there are local dips to the S. W. of which one is 55° S.25°W."

"Limonite, compact and cellular with numerous seams of ocherous earth."

This mine has been completely filled in so there is nothing to be seen.

66. Haines's mine.

"The excavation is 20 feet deep, but has been abandoned for a long time, as there was not sufficient ore to pay for its extraction."

This pit is rather shallow and the sides and bottom are overgrown. All that can be seen is a little yellow clay, a few pieces of lump ore, and some large quartz blocks containing limonitic material.

67. J. & D. Smith's mine.

"Leased by Millerstown Iron Co. Only the most southern excavation is worked, it is about 30 feet deep and is only the surface stripping. From the description in Roger's Final Report, it is evident that the ore occurs in damourite slate and clay."

"Limonite, compact and exceedingly sandy, with considerable adhering yellow clay; the color is various shades of light and dark brown."

This pit is filled with water and the sides are grass-grown. There is some quartz, lump ore, and yellow clay, none of which appears to have much significance.

68. Francis Breinig's mine.

"The large pit is full of water; it has not been worked since 1860, and is said to be exhausted. To the right is a smaller opening, which is being worked at present. The ore occurs in seams and streaks in damourite slate, and the white and yellow clays formed from its decomposition. The clay and ore pitch 18° to 25° S.80°E. The portion of the mine worked is 50 feet deep, and does not exhibit any sign of the ore being exhausted.

"In the northern portion of the field in which the mine is situated a blue ochre is obtained, which is used as a paint. It is probable that this ochre is decomposed Utica shale. To the south of the large abandoned opening there are two smaller ones also full of water."

"Limonite, siliceous, a somewhat slaty structure, and has a spongy form; the color is various shades of brown and brick red."

This pit is filled with water and the sides are covered by trees and brush. There is yellow clay on the banks. Bombshell ore, limestone, some slaty material, quartz containing limonitic material, and silicified material with a slaty structure also are found here.

69. This mine is a short distance west of mine 70. It is several hundred feet long and about 75 feet deep. The bottom and most of the banks are grass-grown and covered with brush. The clay in this pit is predominantly yellow. Limestone is abundant, as is quartz containing limonitic material. Lump and fragmental ore also are to be found.

70. This mine is about the same size as 69, and the bottom and sides are overgrown. Yellow and white clay and a little pyritic material are exposed in the banks. Quartz containing limonitic material is abundant as well as limestone, flint, sericitic material, and lump and fragmental ore. Some of the clay has distinct red streaks that may be due to turgite, which is found here. Some of the clay is light gray.

71. This is a large pit completely overgrown. One small dump at the south end is composed chiefly of yellow and white clay. Here is also found some quartz containing limonite, sericitic material, and a little lump ore.

72. Reuben Butz's & A. C. Belden's mine.

"Leased by the Thomas Iron Co. The mine looks well; the ore occurring in decomposed damourite slate."

This is a small pit almost completely covered by trees and brush. Two small dumps composed chiefly of yellow clay show some limestone, very little quartz, some flint, and fragmental ore which appears to have been bombshell ore.

73 and 74. John Singmaster's mines.

"Leased by the Thomas Iron Co. The ore at present mined is mostly from surface clay. At the single excavation now being worked the ore occurs in yellow clay, together with a very small quantity of white damourite clay. The excavation does not look very well; the ore being taken chiefly from the south end, which had the most promising appearance. The ore is all wash ore. There are several old excavations in which the ore has been exhausted, and which have been filled up."

Mine 73 is a very small pit showing a little limestone and flint. Mine 74 is a large pit with partly grass-grown sides and bottom. Many pits surround the mine and some extend into it. Limestone, brown and yellow clay, and bombshell and fragmental ore are abundant. Sericitic material is common; quartz and flint are rare. Two smaller overgrown pits to the northwest are very similar to 74. However, here limestone is in place, not just float.

75 William Walbert's mine.

"Has been worked but a short time, and the ore at present mined occurs in the surface clay."

This pit has been completely filled.

76 and 77. Stephen Butz's mines.

"The mine is not worked, and the sides are so washed that nothing can be seen."

The two pits that were originally here have been completely filled.

77. Peter Deisher's mine.

"Leased by the Leesport Iron Co. The ore occurs in surface clay, and appears to have been washed into a depression of the limestone, although the latter is not in sight. There is no bedding whatever to the ore or the enclosing clay, while a good deal of quartz and flint occur with them. The ore is all wash ore.

This pit also has been completely filled.

78. Aaron Hertzog's mine.

"This mine has been abandoned, although the machinery is still standing. It consists of a single excavation, in which nothing could be seen."

This pit is completely overgrown. Ground in the vicinity is a dark brown and contains quartz, limestone, and small pieces of lump ore.

79. Wescoe's mine.

"This consists of several pits, none of them very deep; work has long since been abandoned due to the exhaustion of the ore. A large body of white clay was observed in the bottom of the pit."

This is a small pit about 150 feet in the woods from the edge of a field. It is overgrown, but around the edge there is considerable lump ore, some quartz, and big blocks and fragments of Hardyston (sandstone and arkosic varieties).

80, 81 and 82 are in Berks County and hence omitted.

83. J. Barber and Co. mine.

"The ore occurs beneath a blue sandy limestone and over white clay. When seen, the appearance of the pit, where worked, looked badly, there being little or no ore in sight. A short time before work stopped a number of white rounded balls, of considerable weight and various sizes, were found underneath the brown hematite ore, and above the clay. On analysis they proved to be siderite or carbonate of iron of very good quality and the brown hematite has in all probability been formed by the oxidation of the siderite. Only a small quantity of these were found."

"Limonite, compact, and with a large amount of fibrous ore."

This is a small pit filled with water, and the banks overgrown. Very little ore and quartz is to be found. Some Hardyston sandstone may be seen.

84 and 85. Hensinger mines.

"Leased by Allentown Iron Company and Bethlehem Iron Company. These two mines are really one, being merely separated by a thin wall of clay. The ore, as in all the Hensingerville mines, occurs near the top in yellow clay; but this soon changes either to damourite slate, or to the plastic clay resulting from its decomposition. The ore occurs in seams and streaks distributed through the clay or slate. Frequently these streaks, together with the clay, change their course abruptly as if from a sliding of the clay on itself. The clay and ore dip at this mine 28°S.S.E. The ore commences about ten feet from the surface. The mine is about 25 feet deep."

This pit, several hundred feet long, completely flooded, and the banks partly overgrown, is on the property of the Alburtis Rod and Gun Club. Yellow clay, lump ore, siliceous material, and Hardyston sandstone occur here. Some of the siliceous material has a distinct jaspery appearance on the surface. Quartz is present in small amounts, and there is considerable chalcedony and flint. Several dumps at the southwest end of the pit are covered by trees and brush. There is considerable sericitic material in a field just north of the pit.

86. Thomas Iron Company's mine.

"This lies alongside of the pit just mentioned (85) as leased by the Bethlehem Iron Company. The same remark applies to this as to the previous ones that they make a very fine show of ore, the seams appearing to be regular and in great numbers. The quantity of ore is very large and a shaft sunk 75 feet from the surface in the bottom of this excavation still showed ore."

"Limonite, hard, compact, and of somewhat slaty structure."

This is a large but not very deep pit on the property of the Alburtis Rod and Gun Club. The sides and part of the bottom are covered by trees and brush. Exposed sections of the banks show yellow clay, sericitic and siliceous material, some ore, and Hardyston sandstone.

88. John Sharp's mine.

"This mine has not been worked for a long time, and it was impossible to see anything."

This large mine hole is filled with water, and the sides are overgrown. On the banks are yellow clay, lump ore, siliceous material, chalcedony, flint, some quartz containing limonitic material, and Hardyston sandstone.

90. Kiefer's mine.

"Abandoned. This mine was formerly worked by Mr. James Lanigan, but when visited it was impossible to see anything, as the pit had been abandoned for some time."

This pit is surrounded by trees and brush and besides a few fragments of ore and some siliceous material, there is not much to be seen.

91. Hensinger and Saul's mine.

"Leased by the Allentown Iron Company. This mine has two openings, but not so extensively developed as **(84, 85, 86). The position of the ore is the same as that already described, and it appears to be of as good quality."

This pit is completely surrounded by and filled in with trees and brush.

92. Mickley's mine.

"Leased by the Thomas Iron Company. Similar to those just described."

This pit is completely surrounded by and filled in with trees and brush.

93. Harry Kaiser's mine.

"Leased by Mull and Hagenbuch. This mine was not being worked when visited, and nothing could be seen."

"Sample partly lump and partly fine ore. Limonite, hard and sandy, with considerable quartz in fine ore."

This small pit is partly filled with water. Ore is scarce, Hardyston sandstone and considerable jaspery material occur, and other siliceous material is abundant. Several small dumps on the east side of the pit show little.

94. Ludwig's new mine.

"This mine presents a favorable appearance, and pipe ore was found here. In one place a vein of black oxide of manganese was observed 6 to 8 inches thick. Limestone occurs above the ore, but none was seen below it."

This pit has been filled.

95. Butz's mine.

"At this mine the ore occurs in yellow clay, resulting from the decomposition of limestone. When examined the mine did not present a very favorable appearance, there being but little ore apparently distributed through the clay."

This pit has been filled and is indicated by only a slight depression.

96. Ludwig's old mine.

"In this the limestone crops out to the surface, and a vein of ore occurs above the limestone in drift clay. The ore occurs irregularly distributed in the limestone, having the appearance of pockets rather than regular beds. The limestone is horizontal, and presents the curious appearance of having thin layers which have decomposed to an unctuous gray clay."

"Limonite, hard and arenaceous with broken concretions of pipe ore."

This pit has been filled, but some fragmental ore occurs in the vicinity.

97. Jayger's mine.

"Not worked. This mine is only stripping, and at a depth of 10 feet limestone is struck, which is horizontal. The limestone is blue, saccharoidal and waterworn."

This pit has been filled and is represented by a slight depression.

98. Harry Kaiser's mine.

"Leased by the Bethlehem Iron Co. Of the two openings worked, no ore was in sight in the western one, except a very little drift ore in the top. In the east opening one vein, about 8 inches thick, was visible in gravel forming the surface wash."

This pit has been filled, and there is nothing to be seen.

99. Blank's mine.

"Leased by Ludwig, Hertzog & Co. Drift ore occurs immediately beneath the sod, then a bank of clay containing no ore, and underneath this ore and yellow clay the former in thin seams. The seams of ore occur in yellow clay, having a general southerly pitch; this is, however, very irregular, and is sometimes, locally, to the west. The mine, at its deepest part, is down 32 feet."

"Limonite, compact and arenaceous containing cavities lined with goethite and lepidocrocite. Specimen also contained a small piece of arenaceous red hematite, and a small amount of pipe ore."

This is a large pit with the bottom grass-grown and the sides somewhat slumped. Limestone is present in fragments and also in place on the north side of the pit. There is some Hardyston sandstone here. Siliceous and sericitic material are abundant on the northwest side of the pit. Fragments of pipe and bombshell ore are abundant.

100. Meitzler's mine.

"Leased by the Crane Iron Company. This mine has not been worked for some time, owing to the depression in the iron business. The excavation is about 10 feet deep, and a little wash ore could be observed on the sides."

This pit has been filled and there is nothing to be seen.

101. Mickley's mine. This pit is now only a slight depression covered by trees and brush.

102. Desh's mine.

This opening has been abandoned for some time, as all the ore has been extracted. There are two excavations at this point."

The two small pits are completely covered by thick brush and woods so that there is nothing to be seen.

103, 104. Jonas Kreischmann's mines.

"Leased by the Coleraine Iron Company. This mine is about 6 to 8 feet deep. The ore is apparently disintegrated in place or surface ore. It occurs in thin streaks in a yellow clay with considerable flint. A shaft had been sunk 18 feet, and no ore was apparent on the dump. . . . Limestone was struck at a depth of 15 to 20 feet. In another part of the mine a shaft was down 30 feet, and there was but little ore in the clay on the dump. In the northern portion of the mine limestone crops out, having apparently a south-east dip."

Both of these pits have been filled and are now only small depressions. Little is to be seen.

105. Jonas Kreischmann's mine.

"Leased by the Allentown Rolling Mill Co. This mine is only separated (from mine 106) by a fence, and must be identical in its characteristics."

"Vein ore. Limonite, hard, compact, and very sandy."

This is a rather large pit containing several small dumps. The bottom and parts of the sides are grass-grown. Very little quartz, some jaspery material and limestone fragments were seen. Fragmental and lump ore and sericitic material abound. According to the people who own the land, limestone was once taken out from the pit.

106. Ludwig, Hertzog & Liess's mine.

"This ore occurs in seams or bands in the white clay, which has a dip of 27° N.23°W. A great deal of the ore is in lumps, especially at the present bottom of the mine, which is 20 feet. The seams of ore are not regular, but suddenly stop to make a bend and then continue or stop altogether; and another seam will be found a foot or two lower down, and so on. There is a great deal of lump ore.** . . . The ore commences about 5 feet from the surface."

This pit has been filled and is marked now by a small depression.

107. Kerschner's mine.

"Leased by Temple Iron Company. The ore occurs in thin streaks in the clay, and the mine seems to be a good one. There is a good deal of yellow clay on the top, containing no ore, from which bricks are made."

This mine has been completely filled.

108. Henry Shankweiler's mine.

"Leased by John Shaefer. There are two openings at this mine; neither of which has been worked since the panic. The sides were so washed that it was impossible to see anything. The ore apparently occurs associated with the ordinary yellow clay resulting from the decomposition of limestone."

A small overgrown pit; nothing to be seen.

109. Kerschner's mine.

"Leased by Coleraine Iron Company. The mine is about 30 feet deep. The ore forms strings and seams in the clay, and fills up irregular cavities in it. The clays seem to have a dip of 10° S.25°E. The mine presents a good appearance; there being but little flint or quartzite boulders mingled with the clay or ore."

A rather large pit partly filled with water and the sides covered with brush and trees. Quartz, lump and fragmental ore, limestone fragments, and sericitic material were seen.

110. This is a small shallow pit partly filled with water. Occurrences are a few fragments of ore, some yellow clay, and a little quartz containing limonitic material.

111. Gaumer's mine.

"Leased by Temple Iron Company. Not worked when visited; could not see anything or obtain any information about it. The mine is 10 to 15 feet deep."

This pit has been filled and nothing is to be seen.

112. This is a small, rather shallow, and completely overgrown mine hole. The bottom is grass-grown. Several small dumps also are covered by trees and brush. Nothing is to be seen.

113. Smoyer's mine.

"Leased by Bushong & Co. The mine is about 8 feet deep, and in some parts of it limestone is struck at a depth of 5 to 6 feet, while in other parts it was 20 to 25 feet below the surface. The mine is scarcely at a sufficient depth to determine whether the white clay occurs under the ore. To show the cavernous nature of the limestone it is only necessary to state that the well, just alongside, was sunk 40 feet before touching it."

This is a small grass-grown pit surrounded by trees. Nothing is to be seen except a few fragments of ore.

114. Smoyer's mine.

"Abandoned. This has been worked out. It contains two peaks of white clay; one of which comes almost to the surface of the ground. Alongside of these peaks or needles are great cavities, about 30 feet deep, which extend and contained the ore. The bottom of the mine seems to consist of the same white clay."

This is a small grass-grown pit surrounded by trees. A few small pieces of lump ore were seen.

115. Benjamin Smoyer's mine.

"Leased by Shimer and Hartzell, is 10 feet deep; the ore occurs in seams in yellow clay, and has a general dip of 10° N.24°E. Limestone was struck in the well at a depth of 60 feet."

This is another small pit almost in the same condition as mine 114.

116. Smoyer's mine.

"Close to the Little Lehigh Creek, near the point where it is crossed by the Catasauqua and Fogelsville Railroad. The ore occurs in yellow clay, as if the rock were disintegrated in place; no seams or streaks of ore could be perceived. The mine is about 18 feet deep."

At this small grass-bottomed depression surrounded by trees only a few fragments of lump ore were seen.

117. Smoyer's mine.

"Leased by the Millerstown Iron Company, was being opened for the first day's work when visited, so that nothing could be seen. Several trial-pits have been sunk, and it was stated that the indications are favorable."

This mine has been filled in. Pieces of ore may be found in red-brown earth in a slight depression in the field where the mine was located.

118. James Weiler's mine. This pit has been filled in and nothing it to be seen.

119. J. Smoyer's mine. This mine has been completely filled in and nothing is to be seen.

120. Crane and Thomas Iron Co.'s mine.

"This is close to the Trexlertown Church and is bisected by the Catasauqua and Fogelsville Railroad. Not worked at present, and nothing could be seen there to determine the character of the deposit."

The pit is small and almost filled, but near it are many small dumps composed largely of yellow clay. Limestone is rare and a little quartz occurs, some of which contains limonitic material. Chalcedony and flint are present. Bombshell ore is abundant. Some of the bombs are filled with white clay, and some have a core that itself is hollow and composed of concentric layers. Limonite stalacites and fibrous goethite with a glossy black surface are common in these bombs.

121. Frank S. Lichtenwallner's mine.

"Ore very gravelly and mixed with much flint. The appearance of the mine is entirely that of a surface wash of ore and gravel which has been caught in a depression of the limestone. The limestone is struck at a depth of 15 to 30 feet, the latter depth probably in a sink hole. The limestone crops out to the surface very rapidly to the north of the mine, but never above the soil so as to obtain the dip."

"Limonite, compact, with nodular concretions and small seams of ocherous iron ore."

This pit is covered by trees and brush. One small dump shows a little yellow clay, a little quartz and considerable fragmental and lump ore.

122. Smoyer's mine.

"Leased by Thomas Iron Co. The appearance of the mine as to its formation is identical with that of Lichtenwallner's. It is said that limestone is struck at a depth of about 13 feet, but no exposure was seen."

This pit is identical in all respects with mine 121.

123. Smoyer's mine. This mine has been filled in and there is nothing to be seen.

124. Benjamin P. Smoyer's mine.

"Is only stripping, being but ten feet deep. Where left standing white clay is visible."

This pit is almost completely filled and little is to be seen except a few limestone fragments and several small pieces of siliceous material.

125. Judith Smoyer's mine.

"Leased by B. P. Smoyer, had not been worked for some time when visited, and was full of water in the bottom so as to be inaccessible."

This pit, almost completely filled in, is covered by trees and brush, and nothing is to be seen.

126. T. Smoyer's mine. Where this pit was located there is now only a small depression.

127. A. Smoyer's mine.

"Leased by Allentown Iron Co. The ore occurs in seams in the clay with a little flint. As almost the whole excavation was filled with water it was impossible to see much. The dip of the clay taken at one point was 4° S.25°E."

Two small excavations here are surrounded and filled in by trees and brush. Only fragments of ore were seen.

128. R. Romig's mine.

"Leased by the Crane Iron Co. At the junction of the road from New Texas to Emaus and Philadelphia to Mauch Chunk. From what could be seen the ore was apparently in yellow clay. The appearance of the mine indicates disintegration in place; no seams or streaks of the ore could be seen, it being irregularly distributed in small fragments throughout the mass."

This is a large pit filled with water and the sides covered by trees, grass, and brush. There is some relatively pure limestone here, some highly silicified limestone, a little quartz, and a few fragments of ore.

129, 130. P. Romig's mines. Several small openings in which "nothing could be seen."

The former consists of several shallow pits in which may be found some yellow clay, a little lump ore, quartz, and silicified material. The latter mine has been completely filled in.

131. Schmidt and Ritter's mine.

"The character of the mine is the same as . . ." (132-134).

This mine has been filled in. A log-washer dump is covered by trees and brush. Several large lumps of ore and a little quartz and limestone were seen.

132. Werner and Reinhart's mine.

"Leased by Allentown Iron Co. This mine is 75 feet deep, and the ore occurs in seams and streaks in yellow clay. The clay dips 21° N.85°E., probably due to a local roll of the beds."

"Limonite, hard, arenaceous, and compact."

The only evidence of this pit is a small grassed depression.

133. Milton Lauer's mine.

"Leased by Carbon Iron Co. This is really but a continuation of . . . mine (132), being separated from it by a thin wall of clay. In both of these mines about 35 feet of stripping have to be removed before reaching the ore."

"Limonite, hard, compact, and very sandy."

This is a large pit whose sides and bottom are covered by trees, brush, and grass. Limestone crops out on the south side of the pit. It is somewhat shaly and contains a thin bed of limestone pebbles. Limestone found on one bank is highly siliceous. Quartz is present, also bombshell and fragmental ore.

134. Reuben Romig's mine.

"Leased by Allentown Iron Co. The ore occurs in small pieces of wash ore, and as pot ore in yellow and drab clay, probably due to the decomposition of limestone in place. The mine at its deepest point is 36 feet deep and no rock has been struck anywhere. The clay dips 26° S.12°E., coinciding with the limestone dip south of it."

"Limonite, compact and cellular with considerable admixture of clay."

This small pit, almost completely grass-grown, contains several small piles of yellow clay. Most of the limestone is silicified. Quartz and lump ore are present.

135. This is a small pit partly filled with water. The sides show some yellow clay and a little lump ore. Quartz and large blocks of limestone occur here.

136. K. Smoyer's mine.

"Abandoned. Nothing could be seen here; but from what could be learned it did not pay to extract the ore."

The only evidence of this mine is a slight depression.

137. James Scholl's mine.

"This mine, but a hundred feet from . . . mine (138) is identical in character with it. The mine is 14 feet deep."

A very small pit, grass-grown except on one side. Limestone fragments, quartz, and a few pieces of lump ore were found. Siliceous material is abundant and some of the jasper has a slightly granular appearance and contains doubly-terminated quartz crystals.

138. Gernart's mine.

"Leased by Crane Iron Co. This mine is but 12 feet deep, and no ore has been found below this although shafts have been sunk for that purpose. Below the ore sand is found. The appearance here is as if the ore was a mere surface wash caught in a depression of the surface. At one part of the mine a streak of black oxide of manganese was observed in the top clay."

This mine is very small and has the same characteristics as mine 137 which it is directly opposite.

139. Henry Schwartz's and W. B. Fogel's mine.

"Leased by the Crane Iron Co. The mine is 38 feet deep, and dips 13° S.36°E. The bottom of the mine, where worked, shows white saccharoidal sand, and a short distance above it there occurs a bed of white saccharoidal sandstone intercalated in the clay, about one inch thick. The white sandstone contains a little ore, above this occurs a yellow clay and damourite slate, the former forming seams in the latter, which contain ore; above this occurs gravel. The upper part of the clay in and above the slate consists only of stripping, and is not washed."

"Limonite, sandy and contains small cavities lined with goethite."

This pit is filled with water but a small part of the exposed sides shows white and yellow clay. Very little ore is to be found here; a partly grassed dump on the southeast end of the pit shows a small amount of bombshell ore.

140. William B. Fogel's mine.

"Leased by Carbon Iron Co. The ore occurs in damourite slate with an abundance of yellow clay. The yellow clay containing the ore occurs in seams and streaks in the white decomposed damourite slate and clay. The dip of the slate is 14° S.65°E. The mine is 24 feet deep at its greatest depth."

"Limonite, hard, compact, arenaceous, with somewhat of a laminated structure, and a considerable admixture of yellow clay."

This mine has been filled in and nothing is to be seen.

141. This is a long narrow pit filled with water. The sides show some yellow clay. Present also are limestone fragments, quartz containing a little limonitic material, some lump ore, a few pieces of turgite, and much sericitic material.

142. Alwyn Bortz's mine.

"Limonite, compact and argillaceous with a considerable admixture of ocherous earth."

This pit is cut in two by the railroad. Water fills both pits to within 5 to 10 feet of the top. Yellow and brown clay make up the banks. Small fragments of limestone, quartz, and ore are to be found.

143. Alwyn Bortz's mine.

"Leased by the Allentown Rolling Mill Co. This mine is 36 feet deep. Only yellow clay can be seen, in which the ore occurs in small pieces and as bomb-shell."

"Limonite, compact and argillaceous with considerable admixture of ocherous earth."

This pit has been completely filled.

144. Alwyn Bortz's and William Koch's mine.

"Leased by Carbon Iron Co. This forms but a single excavation. White clay occurs here at the west side underlying the ore and having a southeast dip. The mine is 48 feet deep, and limestone is struck 8 feet below, in fact water-worn limestone occurs at west end. The ore is said to have dipped south-east at west end; it dips north-west at south side."

"Limonite, cellular, somewhat nodular, and of a dark brown color."

This pit is about 1,000 feet long and 75 to 100 feet wide, and is completely filled with water. Exposed sections of the banks show yellow clay. Only fragments of quartz, limestone, and ore are to be found. A large dump at the east end of the pit is composed of red, yellow, and brown clay, and some black clayey material containing weathered pyrite.

145. Jonas Grammis' mine.

"Leased by Allentown Rolling Mill Co. The ore occurs in yellow clay above white clay. The dip of the clay is east and south-east, but irregular."

"Limonite, soft and cellular with some of the cells being filled with yellow clay; partly laminated structure."

This small flooded pit is northeast of and has the same charecteristics as mine 144.

146. Jonas Grammis' mine.

"Not worked. This mine is 25 feet to water, but was inaccessible, and therefore could not be examined."

"Limonite, soft and cellular with some of the cells being filled with yellow clay; partly laminated structure."

This pit has been completely filled.

147. This fairly large pit filled with water has several small dumps at one end. Parts of the sides are grass-grown, but show some yellow clay. Quartz and limestone fragments, considerable lump ore and turgite, and a little sericitic material are present.

148. Gackenbach's mine.

"Leased by the Crane Iron Co. The ore occurs in this mine in yellow clay, and no damourite-slate or white clay occurs with it, so far as could be seen. There are two beds of ore in the mine, the upper one about 10 feet thick, which are separated by clay. Water-worn limestone was struck, in some places, at a depth of 60 feet; no ore was found under this, but in clay in depressions in it. The ore occurs in and above the clay, and not in the limestone. The mine is 72 feet deep to the water, and there were about 20 feet of water in it when visited.

"A portion of the ore is called 'red rock ore' and appears red besides having a red streak. It is probably limonite rendered anhydrous by some local cause. The ore in the bottom is said to be very fine and almost solid."

"Limonite, stalactitic, cellular, and sandy; the color is various shades of brown and vermillion; contains 10.83% water."

This pit is several hundred feet long and about 100 feet wide. It is very deep and the bottom is filled with water. The banks are composed of yellow and red clay. Limestone is found abundant, but only one block was found in place, and this was silicified, weathered, and parts of it had a shaly appearance. Fragments of low grade ore and of pure and weathered quartz were seen. There are several large dumps on the opposite side of the road from the pit.

149. This is a small mine hole filled with trees and brush. Two small dumps show yellow clay, quartz, sericitic and siliceous material, and lump ore.

150. This is a long, narrow, and fairly shallow pit. The banks are covered by trees, brush, and grass. Yellow clay is exposed on the banks and quartz, siliceous material, and a little lump and fragmental ore.

151. Jonas Bastian's mine.

"Abandoned. Shafts have been sunk to quite a depth in the bottom of the mine; but the stuff at the mouth of the shafts has been nearly all washed away. The mine is from 10 to 15 feet deep; near the surface it is apparently ore disintegrated with the rock in place; near the bottom of the mine the ore appears in one or two places to form beds in the clay."

This is a large pit partly filled with water. There is very little limestone here, some quartz, and a little ore. Most of the rock appears to be highly silicified. Another flooded pit just to the north shows the same characteristics.

152. Elwyn Bastian's mine.

"Leased by the Lehigh Iron Co. The mine is 22 feet deep to the water. Ore occurs in clay, the latter varies from level to a dip of 5° S.18°W."

"Limonite, hard, compact, and sandy with considerable quartz in the fine ore."

This is a small mine with two rather large dumps which are covered by trees and brush. There is very little to be seen here except a little quartz, lump ore, and some material which appears to be highly silicified.

153. Francis Guth's mine.

"Leased by the Carbon Iron Co. There are three excavations at this mine."

"Limonite, hard, compact, and sandy."

Of the three excavations here the middle one is by far the largest and is partly filled with water. There is some yellow clay here, a little quartz, and considerable siliceous material. Lump ore is abundant and ranges in size from small pebbles to rocks one to two feet in diameter.

154. Francis Fischer's mine.

"Leased by the Coleraine Iron Co. In this mine no rock is apparent, nor has any been struck. The ore occurs as wash and pot ore in yellow clay probably resulting from the decomposition of the limestone. At the east end the clay basins slightly, and dips 30° S.67°E. The mine is 36 feet deep."

"Limonite, arenaceous, and exceedingly hard and tough with nodular concretions and velvety surface."

There are two excavations here. The one nearer to the road is covered by trees and brush, and has a small dump at one end. The second pit is several hundred feet long, about 50 feet wide, and is flooded to within 35 feet of the top. The banks are composed of yellow clay and brownish earth. Quartz, ore, and limestone fragments occur here. The jaspery material has a granular appearance and contains some doubly-terminated quartz crystals.

155. John Woodring's mine.

"Leased by the Crane Iron Co. This mine was not being worked when visited and the sides were much washed. The ore occurs in yellow clay, which was plastic and looked as if it were decomposed damourite. On the dump there was a little white clay, showing that it occurs in the mine. In the northeast corner of the main opening a little waterworn limestone can be seen."

This pit has been filled. Its small dump covered with trees and brush shows a little yellow clay.

156. Charles Glick's mine.

"Leased by the Allentown Iron Co. At present the pit is only being stripped to a depth of about 8 feet, the old excavation having been filled up as a mud-dam. No ore has yet been found at a greater depth than that above given. It looks as if the ore had merely been washed into a depression in the limestone."

"Lump ore, compact and cellular with considerable adhering clay; the color is a dark brown."

This pit has been filled. A few fragments of quartz and limestone occur in the field.

157. L. Glick's mine.

"This mine, which is 20 feet deep, was not working and but little could be seen. The ore apparently occurs in Drift."

Yellow clay, quartz, and ore fragments can be found at this small mine hole that is partly covered by trees and brush.

158. John Roth's mine.

"Leased by the Allentown Iron Co. The ore occurs in yellow clay, which seems to be decomposed damourite slate."

"Lump ore; exceedingly compact and fine-grained; dark brown."

The mine is in the same condition as mine 157.

159. H. Kemry and Carbon Iron Company mine.

"The east end of the pit belongs to Kemry, the west end to the Carbon Iron Co.** The ore commences 5 feet from the top, forming strings and seams in the white clay. In the bottom a thicker bed occurs, almost horizontal. Yellow damourite slate occurs in the pit. The white clay at one point in the west end of the mine, forms a bed 6 feet thick, free from ore. This excavation apparently contains more ore than the other mines of this group, but there is also more yellow clay associated with it than in many of the others. The mine presented a favorable appearance, and will undoubtedly be worked again when the iron business improves."

This is a very large pit, grass-bottomed. The sides are exposed and consist of yellow clay with a little ore. A hole in the one bank illustrates the relation between the ore and the clay. White clay is common. Limestone and quartz are abundant and deeply weathered. On the left side of the road leading into the pit there is limestone in place. Both lump and fragmental ore are abundant.

160, 161, 162, 164. Henry and Leon Schmoyer's mines.

(162) "Is grass-grown, but white clay can be seen on one side of the pit. (164) is not working, and the sides are much washed; it shows white clay near the surface, with yellow clay containing more or less ore below it. The relative quantity of ore cannot be seen. (161) is in precisely the same condition as (164), from which it is separated by a ridge of ground which has not been worked. (160) which has been the most extensively mined, is also not working. At the west end the ore is found in yellow clay within 6 feet of the surface. At the most southerly point of the excavation, near the stack, a large body of white clay rises to the surface containing flint and saccharoidal sandstone. The latter apparently forms a layer about 8 inches thick, out of reach in a vertical wall of white clay. There is a good breast of ore directly under the stack. This pit looks well, the main difficulty in working it being the heavy stripping in some places."

In the latter three mines there is not much to be seen since they are almost completely covered by trees and brush. However, exposed portions of the banks show some yellow clay, quartz containing limonitic material, limestone fragments, and a little lump ore. These three pits are very close together, and mines 164 and 161 are separated only by a small wall of clay. Mine 160 has been almost completely filled in, but what is left of it is very similiar in all respects to mine 159.

163. Jacob Steiner's and Solomon Kehm's mine.

"The former, which is the most easterly of the excavation, is leased by the Lehigh Iron Co.; the latter, which lies westerly, is leased by the Emaus Iron Co. To the east of the main excavation are two smaller ones, the nearest of which is 30 feet deep and grass-grown, the further one is not worked and there is so much water in the bottom that it is inaccessible. The Emaus Iron Co. are working their portion of the pit. In the extreme west end there is a good body of ore and clay, 20 feet thick, and above it white and pink clay. Near this a very small quantity of pyrite altered to limonite, occurs in the clay, the mineral occurring in small lenticular shaped masses. On the south side there is a great bed of white clay, 6 feet thick, containing no ore, but there is ore underneath it. There are everywhere seams of white clay through the ore. The mine presents a rather favorable appearance, the chief difficulty in working it is the heavy body of clay above the ore which has to be stripped off. The Lehigh Iron Co. are not working their part of the excavation, which on their side is only 20 feet deep. On their side, however, the ore comes within 6 feet of the surface and the white clay within 18 inches. The ore and clay are almost horizontal, but are undulatory, so as to have no very regular dip."

"Lump ore, hard, compact, and tough; carries some particles of quartz and considerable adhering clay."

This pit is now almost completely filled except one end which is covered by grass and brush so that nothing can be seen.

165. Reinhart's mine.

"Leased by the Allentown Iron Co. At the top there are about 5 feet of surface soil, succeeded by brown, drab and white clay with ore, having a depth of about 20 feet. In the centre of the mine the ore looks well in the bottom of the excavation. There is plenty of decomposing damourite slate in the north end of the mine. On the piles of refuse in the excavation there is an abundance of small pieces of slaty limestone, but none could be seen in place. The appearance of this pit is a good one. Adjoining this there is a small pit, 12 feet deep, which contains ore in white clay. This latter is not so extensively opened, nor does it look as well as the former one."

This is a relatively shallow pit covering a large area. Several small mud-dam deposits are present. Fragments of bombshell ore are numerous, some quartz containing limonitic material, silicified limestone, and a small amount of lump ore. Yellow clay makes up most of the dumps.

166. H. and F. Jobst's mine.

"The ore is all wash ore, and is irregularly distributed in the clay in which it occurs."

"Wash ore; rather compact, shelly with a large amount of clay."

This pit, adjacent to mine 165, is much smaller, and is partly covered by trees and brush. Nothing is to be seen.

167. Crane Iron Company's mine.

"At the junction of the road from New Texas to Emaus, and Millerstown to Allentown. The most western of the three openings belonging to this company was not worked, and nothing could be observed. The middle mine at the north corner of the junction of the two roads was being worked. It has been excavated to a depth of 40 feet, and the regular bed of ore is still at the bottom; there being more an appearance of distintegrated or drift ore near the surface. The ore occurs with clay. But little pot or bomb-shell ore was observed. The third mine belonging to the Crane Company lies at the eastern corner of the cross-roads, and was abandoned; nothing could be seen there."

This small pit with a shaft is covered by trees and brush. There is very little ore, some silicified limestone, and a little quartz and sericitic material.

168. Thomas Iron Co.'s mine.

"Not being worked when visited, its character is apparently identical with that of Frank S. Lichtenwallner's mine (121).

A dump and small depression are all that remain of this mine.

169. Allentown Iron Co.'s mine.

"At the western junction of the cross-roads. This mine has been formerly worked to an inconsiderable depth on the surface for ore, and abandoned as being exhausted. The Allentown Iron Company then took hold of it and sunk shafts on to the ore in place. The ore, like that in the Crane (mine) just mentioned, presents a fine appearance, forming a regular bed on the clay. The ore at these cross-roads lies deep. The trial-shafts were sunk 25 feet at this mine before striking ore in place."

Several small dumps give the location of this mine. There is considerable yellow clay, some quartz, and siliceous limestone here. Ore is very scarce.

170. This is a fairly large, rather deep pit. It is completely covered by trees and brush except one side shows some yellow clay, limestone blocks, sericitic material, and rather massive lump ore, also some fragmental ore, flint, and quartz.

171. Wenner's mine.

"Leased by the Crane Iron Co. The pit is 10 to 20 feet deep, but not deep enough to see much as to the condition in which the ore occurs. In the very bottom there is a little white clay. A little of the ore is lump, but the greater part is wash ore."

This pit is very shallow and so overgrown that little is to be seen.

172. Wiand's mine.

"Leased by the Temple Iron Company. It makes a fine show, and has been worked very extensively, now being exhausted unless fresh ore should be struck at a greater depth, which there is no reason to expect. The mine is about 30 to 40 feet deep. In some places limestone is struck at a depth of 25 feet, while in other parts of the mine shafts have been sunk to a depth of 50 feet before meeting it. The ore is partly wash ore near the surface; deeper, it forms seams in the clay; occasionally pot ore occurs. In some places the mine is being worked in 7 to 9 feet of solid ore."

"Sandy limonite with considerable quartz in the fine ore."

This pit is similiar in all its characteristics with mine 171.

173. P. Marck's mine.

"Leased by Lehigh Iron Company. It consists only of stripping, the mine not being worked to a greater depth than 5 feet."

"Limonite, hard, compact, and arenaceous with somewhat of a slaty structure."

This pit has been completely filled.

174. Reuben Laros' mine.

"Leased by Hartzell and Keck. When visited it was only 8 feet deep, having been but recently opened. On the dump all the ore seems light, and looks very slaty. In the bottom of the present openings about 6 inches of yellow (damourite?) clay can be seen, in which most of the ore apparently occurs."

This pit is very small and overgrown by trees and brush. Little is to be seen except a small amount of yellow clay, some sericitic material, quartz, and fragmental ore.

175. This small pit located in a patch of woods shows nothing, but in a adjacent field one can find Hardyston sandstone, quartz, and jasperoid materials.

175½. Near crest of hill about one mile east of Shimersville some limonite ore was mined. It is within the Hardyston formation.

176. Shelly's mine.

"Leased by ...... Shankweiler. This pit is 10 feet deep; there is about 5 feet of clay on top, while the ore occurs in strings and veins in the damourite slate. The mine *** has been but little opened. From what could be seen the mine looks promising."

This pit is about 150 feet long and 50 feet wide, and is surrounded by trees and brush. According to the landowner, soundings with a 100-foot rope did not touch bottom. Yellow clay is exposed on the sides. The ore is closely associated and mixed with the Hardyston sandstone and jasperoid material. A small dump at the north end of the pit shows yellow clay and sandy material which has apparently been used for sand.

177. Elias Daney's mine.

"Leased by the Coleraine Iron Co. The ore occurs associated with white clay, but the pit had not been worked for three years when visited, and consequently the sides were so washed, and there was so much water in the bottom, that it was impossible to see anything."

This fairly large pit and a small dump at the north end are covered by brush and trees. In an old dirt road running alongside the mine there is considerable siliceous material, gneiss, flint, Hardyston of the arkosic and sandstone varieties, and some limonite ore mixed with quartzite and jasperoid material.

178. Daniel Schwartz's mine.

"There are about 15 feet of surface soil above the clay and ore. In the west end there is a mass of flint or quartzite colored black by iron and intermingled with the ore, which is all broken up. Over which lies bedded gray flint, and beneath the ore white clay. In the middle and east end the show of ore is better. The pit is worked at these points and contains ore as far down as it is worked. Where seen clay occurs intermingled with and apparently underlies the ore. In the east end the ore apparently dips southeast. The middle of the mine is leaner than the east end. The mine has been worked many years and a large amount of ore taken out of it, but present appearances would indicate that it is not far from being exhausted."

This pit is about 200 feet long and 100 feet wide and is completely filled with water. The exposed banks show yellow clay, quartz, flint, chalcedony, and lump and fragmental ore. Most of the banks are covered by trees and brush. Considerable siliceous material is present. The Hardyston is represented by both the arkosic and sandstone varieties. Some of the ore is intermingled with the siliceous material.

179. Emaus Iron Co.'s mine.

"The mine is 10 feet deep and not worked. The ore, of which there is very little in sight, occurs in drift deposits of Potsdam sandstone. The mine did not look promising."

This is a large pit completely filled with water. Exposed banks show yellow clay, a little ore and considerable siliceous material. Hardyston of the sandstone variety and some quartz are also found.

180. Nathan Whitely's mine.

"At this mine, about 15 feet deep, the ore occurs in clay containing a great deal of flint. A good deal of the ore is pot or bomb-shell. Limestone crops up in the bottom at very varying depths owing to its having been so much water-worn. From one of the limestone caverns, water bubbles up very rapidly. The ore dips 15° S.60°E. The mud from the mud-dam, which is ochre-yellow, is carefully dried and then sent as ochre to the Blue Mountain Paint Company at Bethlehem."

"Limonite, hard and arenaceous; structure flaggy and some of the pieces decidedly fibrous."

This pit is almost filled with water. Yellow clay occurs on the banks and on a small island. Quartz, limestone, and fragmental and lump ore are fairly abundant.

181. This is a small shallow pit completely covered by trees and brush. Little is to be seen except a few fragments of limestone and quartz.

182. Thomas Breinig's mine.

"Leased by the Northampton Iron Co. This is one of the oldest mines in the county, having been worked more than sixty years. The old portion of the mine is full of water and said to be 60 feet deep. The ore occurs above damourite slate, and associated with iron pyrites. It is improbable that the sulphuret of iron owes its origin to a small shallow bed of Utica shale which has undergone disintegration. It was impossible to ascertain whether the blue ochre occurred here or not. The most probable explanation of the formation of iron pyrites, which occurs as a pipe-shaped stalactite, is that sulphate of iron in solution, coming in contact with organic matter, or possibly the graphite of the blue ochre, was reduced to sulphide of iron. That the sulphide of iron is not a deposit cotemporaneous with the rock, is evident from its stalactitic character. Black oxide of manganese occurs here, but it was impossible to see any of it owing to the conditions of the mine."

"A thin bed of white saccharoidal sandstones occurs in this mine; pieces of it were observed thrown up on the bank. Mr. Breinig states that the brown hematite occurs above and below this, but not in it. Pieces of sandstone colored red by iron were observed on the dump. To the west of the old mine a new excavation has been recently commenced."

"Limonite, very compact, somewhat cellular and stalactitic; botryoidal; the color is various shades of brown."

Two pits filled with water and two large dumps of yellow clay and a black clayey pyritic material mark the spot. Limonite lump ore and turgite are abundant; also slaty material, limestone fragments, and quartz containing limonite.

183. Oliver Moser's mine.

"Leased by the Northampton Iron Co. This mine has only recently been opened to a depth of 5 or 6 feet."

"Limonite, compact mass of ore, the pipes in some places being somewhat obliterated, somewhat cellular, the cells being partially filled with yellow clay; the color is dark brown generally."

This pit has been completely filled.

184. This large pit is almost filled with water and the sides are covered by trees and brush. Blocks of limestone are in place on the south side of the pit, and a few pieces of ore, quartz, and limestone occur along the edges.

185. This very small hole partly filled with water is slightly southeast of mine 184. Yellow clay is exposed on the banks, and in the road running alongside the pit there are small pieces of lump ore, and a little limestone.

186. Daniel C. Kline's mine.

"Located about 800 feet southeast of the Coleraine Iron Co.'s mine (originally Desh's mine) in the south edge of Leipert's gap. The limonite occurs in decomposed hydro-mica slate. The laminations or dip of the slate is S.25°-30°. The dip is variable and ranges from S.10°W. to S.10°E."

This small pit is filled with water and the sides are covered by trees and brush. The exposed sides show yellow clay. Considerable massive and brecciated red to brown jaspery material and large blocks of ore are closely associated. The sandstone phase of the Hardyston is present, and other siliceous material resembling chalcedony and flint is abundant. Some gneiss and silicified limestone also are found here.

187. Desh's mine.

"A small opening; too little worked to judge as to the value of the locality."

The bottom of this small mine hole is covered with water and the sides with trees and brush. Several large dumps at the west end have been dug into and show yellow clay, lump ore, a little turgite, and streaks of red clay. Hardyston sandstone, flint, quartz, and dense, massive jasper also are found here. The ore is closely associated with the jasper and Hardyston sandstone.

188, 189. Charles Bader's mines.

"Leased by the Allentown Iron Co. These mines are not worked and there is only white clay in sight."

These two mines could not be located and have evidently been filled in.

190. Trexler and Kline's mine.

"This pit is now abandoned and apparently exhausted, having been worked to the underlying Potsdam sandstone. White clay has immediately overlaid the sandstone, since remains of it can be seen in the crevices on the upper surface of the latter. It may be possible, although not probable, that more ore will be found on descending deeper. At this pit, also, white clay underlies the ore."

"Lump ore, compact, arenaceous, and a dark brown."

This is a small pit partly filled by water from a spring at the base of the mountain. A large dump at the northeast end is covered by trees and brush. Hardyston of the sandstone and arkosic varieties, other siliceous material, and some ore closely associated with the Hardyston sandstone are found here.

191, 193. Henry Kline's mines.

"These were only small pits, abandoned and in which nothing could be seen."

Mine 191 is an elongated, narrow very shallow pit almost completely covered by trees and brush. A large dump at the western end shows yellow clayey material with lump ore which the old-timers called "bullfrog" ore; also gneiss, Hardyston sandstone, and other siliceous material. At one time turgite was the chief ore mined here. Mine 193, a very shallow pit covered by grass and brush, has the same characteristics as mine 191.

192. Mine 192 has been completely filled in and nothing is to be seen.

194. Jesse Kline's mine.

"In this pit, now abandoned, the ore and clay can be seen conformable with the underlying Potsdam sandstone, the latter containing *Scolithus*. There are places where it looks almost as if the sandstone was running into limonite."

"Lump ore. Compact; also cellular and bomb-shell with considerable clay."

This is a large pit surrounded and filled by trees and brush. There is not much to be seen. Yellow clay is exposed in the bank. Gneiss, Hardyston sandstone, jaspery material, and lump ore occur here.

195. Henry Kline's mine.

"Leased by Jobst and ———. There are two openings here. At the smaller one, which lies just below the gneiss of South Mountain there was a small nest of black oxide of manganese, 8 inches thick, which has since been worked out. The ore lay directly against the Potsdam sandstone. There is white clay in this pit, which is very gritty and is in part decomposed Potsdam sandstone. The gneiss, under the sandstone, is granitic, very quartzose and contains a little matite or red hematite. In the larger pit the mine had been only re-worked a single day when visited. There was not much ore in sight, the little that was seen, lying in white and yellow clay. At the east end there is Potsdam sandstone in the bottom, apparently in place, with an undeterminable dip. The ore here is very close to the sandstone and must be sought for in depth."

"Lump ore, sandy and shelly with the ore carrying considerable quartz; the color is a dark brown."

This pit is much smaller than mine 194 but is similar to it in all respects.

196. Henry Kline's mine.

"At this pit, which is abandoned, nothing can be seen. A shaft has been sunk through the clay 30 or 40 feet, but from the character of the material on the dump little or no ore has been found."

This large pit is filled with water and the sides are covered by trees and brush. Exposed banks show yellow clay. Several dumps surrounding the pit are covered by trees and brush and show very little. Gneiss, Hardyston of the sandstone and arkosic varieties, flint and chalcedony, jaspery material with ore, and some lump ore are found here. The ore is intermingled with the jasper.

197, 198, 199. Martin Kemmerer's mines.

"The first pit is abandoned and full of water. Shafts have been sunk around it and again filled up. On the dumps can be seen a little pipe ore and white clay. The ore has either been exhausted, or deeper, workable deposits of ore have not been touched by the shafts."

Mine 197 is a small, very shallow pit surrounded and partly filled in by trees and brush. Yellow clay is exposed in one of the banks, also gneiss, Hardyston sandstone, and jasper. The ore is closely associated with the jasper and Hardyston sandstone. Mine 198 is a very small pit with some water in it and has the same characteristics as 197. Mine 199 is very small and partly filled with water. Little is to be seen here except some gneiss and jasper.

200, 201. Keck and Ritter's mines.

"Leased by Emaus Iron Co. Mine (200) is abandoned and no ore can be seen on the banks. In (201) the ore is sporadically distributed in yellow clay. Not far from the bottom there is a bed of white clay about 6 inches thick. It may be that the ore in the bottom is in place, but it does not present that appearance. There is a great deal of flint associated with the ore. The mine does not present a very promising appearance."

"Lump ore, sandy, compact, and nodular with specks of quartz."

Mine 200 is a fairly large pit, surrounded by dumps, and all covered by trees and brush. A little gneiss, and ore associated with jasper and Hardyston sandstone. Mine 201 is a small pit partly filled with water and covered by trees and brush. Two large dumps are covered by trees and brush but show yellow clay. Gneiss, Hardyston sandstone, and lump ore containing jaspery material are found here.

202, 203, 204. G. Kline's mines.

"(202) is abandoned; there is a great deal of lump ore on the dump. The sides are caved in, but at one point the Potsdam sandstone was seen decomposed to a beautiful variegated sand. The ore was taken from clay and damourite slate directly overlying the sandstone. Of the two pits at (203), the southerly one shows nothing. A drift has been driven in close to it, in which nothing can be distinguished, and which does not penetrate very far. On the other pit and at (204) nothing can be seen, but a number of shafts have been sunk and there is quite a good deal of lump ore on the dumps, apparently enough to pay for working when the present depressed period in the iron industry improves."

Mine 202 is a large pit partly surrounded by dumps which are covered by trees and brush. The bottom of the pit is grass-grown. There is yellow clay on the dumps. Gneiss, chalcedony, very little Hardyston sandstone, some lump ore, and considerable jasper occur here. Mine 203 is a large pit filled with dark blue or black water. The pit is about 65 feet deep and is surrounded by trees and brush. Several large dumps at the southern end have considerable gneiss, Hardyston sandstone, chalcedony, and massive, dense jasper with which the ore is associated. A few pits may be seen at one end of the mine. Mine 204 is very small and partly filled with water. It is adjacent to mine 203, and its banks and several small dumps are covered by trees and brush. Gneiss, a little Hardyston sandstone, lump ore, and jasper are found here.

205. This small pit is rather long, narrow, and fairly deep. It and several small dumps at one end are almost completely covered by trees and brush so that nothing can be seen. On an old road alongside the pit there is some gneiss, Hardyston sandstone, and jasper.

206. A shallow pit covered by trees and brush, and two small dumps close by show nothing.

207. A large shallow pit, covered by trees and brush. A small dump at one end shows a little yellow clay.

208, 209. Stein's mines.

(208) "is not being worked and the sides are so much washed that nothing can be seen. In places sand occurs which looks like decomposed gneiss. (209) is abandoned and grass-grown."

Mine 208 is several hundred feet long, about 75 feet deep, almost completely covered by trees and brush. Yellow clay occurs at the southwest end. Here also are large blocks of jasper apparently in place, gneiss, siliceous material, Hardyston sandstone and lump ore. Mine 209 is very small and about 25 feet deep. Small pieces of lump ore are closely associated with outcrops of large blocks of massive, dense jasper. Several small dumps show nothing.

210. This long, narrow, and shallow pit almost completely covered by trees, grass, and brush so that very little is to be seen.

211. This mine is about the same size and condition as 210 except a few fragments of jasper and gneiss lying around.

212, 213. Hottenstein's mines.

"Potsdam sandstone underlies and overhangs pit ** (212) and in this there are boulders of sandstone. At ** (213), which is also not worked, there is sandstone in the west end, probably boulders. But nothing could be seen relating to the nature and position of the ore."

Pit 212 is long and narrow, fairly deep, and covered by trees and brush, as are several small dumps. Large blocks of Hardyston sandstone and brown, red, dense, massive jasper occur at the eastern end of the pit. Gneiss, siliceous material, and lump ore are present, some of the ore being intermingled with the jasper. Yellow clay is exposed on one of the banks. Pit 213 is much smaller, fairly deep, and is in the same condition as 212.

214. Milton Apple's mine.

"At this pit there are boulders of Potsdam sandstone and debris from which ore has been taken. A shaft, 20 feet deep, shows the same in the bottom."

This pit is slightly smaller than mine 215 and is separated from it by a wall of jasper and Hardyston. It is covered by trees and brush, but some yellow clay is exposed in one of the banks. Large boulders of jasper and Hardyston sandstone are here and some siliceous material and gneiss.

215. Kipping and Holsbach's mine.

"This pit was not being worked. Only yellow clay and drift could be seen, there being no ore in sight. At one point a drift has been run in, which is now fallen shut."

This mine is long, narrow, relatively deep, and the sides and bottom are covered by grass, trees, and brush. Some yellow clay is exposed. Large blocks of red and brown, dense, massive jasper and Hardyston sandstone are in place on the southwest side of the pit. Some of the blocks are 15 to 20 feet in diameter. There is some siliceous material, gneiss, and flint. The ore is both lump ore and closely associated with the jasper.

216, 217, 218, 219. Conrad Seam's mines.

"At (217) can be seen surface drift, then white clay, next ore and finally white clay again to the top of the water in the bottom of the pit; the appearance of the ore is good. (216) was being worked for the Allentown Iron Co. The ore occurs in white and yellow clay. (218), which is not being worked, shows ore on the south side in white clay. (219) was not being worked."

"Lump and wash ore. Hard, tough, botryoidal, and a reddish brown. The ore carries considerable adhering clay."

Mine 216 is a small pit almost completely covered by trees and brush. Considerable dense and massive jasper and Hardyston sandstone are present, and a little ore which is closely associated with the jasper. Mines 217 and 218 are on the City of Allentown's reservoir property. These have been filled in, but the adjacent dumps contain considerable quartz (some including limonitic material), gneiss, and Hardyston sandstone. Yellow clay is exposed on the banks. Some of the Hardyston sandstone and jasper are in boulders several feet in diameter. The Hardyston is of the sandstone and conglomeratic types. The ore is both lump and mixed with jasper. Several shafts just above these pits are now almost completely filled in. Mine 219, just off the road running around the reservoir, is filled with water. Some yellow clay is exposed, and pieces of jasper, gneiss, and Hardyston sandstone in all sizes. Lump ore, some fragmental ore, and jasper containing abundant ore are to be found.

220, 221, 222. Whitman's mines.

"Leased by Emaus Iron Co. (220) is being worked; the ore occurs in white and yellow clay, there being but little ore in sight when the mine was visited. (221) and (22) are numerous small openings not worked and the sides too much washed to see anything."

Mine 220 is a large pit much filled with water, and surrounded by dumps, all covered by trees and brush. It is just a short distance north of mine 219. The banks show some yellow clay. Here occur large amounts of gneiss, siliceous material (chiefly chalcedony and flint), brown, dense, massive jasper, and lump ore. Hardyston sandstone is scarce. Mine 221 is a very small and shallow pit surrounded and filled by trees and brush. Gneiss, quartz, and jasper were seen here. Mine 222 is about the same size as 221 and in the same condition. Several dumps around this pit are covered by trees and brush but show some yellow clay, gneiss, jasper, and ore.

226. This small mine hole is partly filled with water. The sides show yellow clay, limestone fragments, sericitic material, lump and fragmental ore, and quartz containing limonitic material.

227. This large mine hole is filled with water. The banks are mostly covered with trees and brush, but where exposed they show some yellow and white clay. There is considerable quartz here, some of it containing limonitic material, also limestone fragments, sericitic materials, lump and fragmental ore. Several small dumps around the mine are covered by trees and brush and show very little.

228. The bottom of this small mine is partly flooded and partly in grass. The banks are covered by brush and grass, but show some yellow clay, limestone fragments, sericitic material, and a little lump and fragmental ore. Some of the quartz contains limonite.

229. This large pit is filled with water. The sides are covered by trees and brush, but show some yellow clay. Several small dumps around the pit are covered by trees and brush and consequently show very little. Lump and fragmental ore, limestone, sericitic material, and considerable quartz with limonite occur nearby.

230. This pit is just a few feet south of 229 and is like it in all its features.

231. This large mine hole several hundred feet southwest of mine 230 is similiar to mines 230 and 229.

232, 233, 234. These constitute one very large mine hole which is filled with water and the sides covered by trees and brush. Exposures on the sides show some yellow clay. Limestone fragments, some apparently silicified, and limonitic quartz are abundant. Lump and fragmental ore and turgite occur here. A large dump south of the pit shows yellow and white clay, black clayey material (decomposed pyrite), flint, and jasper, which is somewhat granular and contains doubly-terminated quartz crystals. Sericitic material is present, and siliceous material which is almost a cross between quartz and jasper.

235. This small mine hole is partly filled with water. The banks are exposed and show some yellow clay, limestone fragments, considerable quartz containing limonitic material, and some rather massive lump ore. Jasper with doubly-terminated quartz crystals is also found here.

236. This large mine hole is filled with water. The sides are mostly covered by trees and brush. Some yellow clay is present, also lump ore, turgite, sericitic material, and large amounts of quartz, some of which contains limonite stains. The fragmental ore has the appearance of being the remnants of bombshell ore. Some of the lump ore is massive and contains fragments of quartz and limestone. A large dump at the southwest end of the pit is covered by trees and brush.

237. This very large mine hole is filled with water. The sides are covered by trees and brush. This pit has the same minerals as 236.

238. This pit is filled in and nothing is to be seen.

239. The bottom and banks of this small, shallow mine, are grass-grown, and covered by trees. The ore is closely associated with abundant siliceous material. The jaspery material is massive and dense, and some of it is brecciated. Hardyston of the arkosic and sandstone phases is rather abundant.

240. Wint's mine.

"The limonite occurs in lenticular bodies in decomposed sandy hydromica slate. Thin beds of limestone have been found in the mine. The ore deposit is irregular. The dips observed are W.10°-15° and S.45°W.15°. The mine appears to be located near the base of the slates. The ore is very siliceous, owing to the large amount of sand which occurs in the slate."

This is a large mine hole 60 feet deep and filled with water. Good ore at the bottom averaged about 40 percent iron. A large dump on the northeast edge of the pit shows considerable yellow clay. Limestone fragments, considerable quartz containing limonitic material, massive lump ore, and many fragments of siliceous rock containing limonite occur here.

241. This large mine hole is covered by trees and brush. Several large dumps in the middle of the pit show yellow clay, lump and fragmental ore, limestone fragments, a few small blocks of Hardyston sandstone, quartz, and considerable sericitic material, and granular jaspery material.

242. This large pit is filled with water. The sides show some yellow clay. There is limestone, a little quartz, some lump and fragmental ore, and a few small blocks of brown, massive jasper. A small pit on the opposite side of the road probably once was part of a this mine.

243. This mine has been filled in and nothing is to be seen.

244. Completely covered by trees and brush and partly filled with refuse.

245. A large pit whose sides and bottom are covered by trees and brush. There is a small yellow clay bank in the mine, and a small amount of jaspery material that contains some ore. Some Hardyston sandstone also is present.

246. Sill and Jordan's mine.

"There are several small openings 20 to 30 feet deep and 10 to 20 feet wide. The limonite occurs in clay and sand, no slate is visible. A small lenticular deposit of specular ore occurs in one of the excavations. The limonite is deposited irregularly in the clay and sand. The deposit appears to be in the Potsdam sandstone. There appears however to be no Potsdam sandstone between the limestone and feldspathic rocks at Centre Valley."

Two adjoining pits, the northeast one the smaller and partly filled with water, the other much larger and the bottom covered by brush and water. Yellow clay is exposed in the banks of both pits. There are large blocks of gneiss, Hardyston sandstone, and jasper lying around. The jasper is yellow and red and contains some ore. Pyrite occurs in a large block of slightly weathered sandstone.

248. Newmeyer's mine.

"The limonite occurs in decomposed hydro-mica slate and clay; and from the position of the mine, the slate appears to be equivalent to that overlying the limestone of the quarries at Limeport."

This is a large pit filled with water. The sides of the pit and a large dump near by are covered by trees and brush. Lump ore is common and most of it is associated with jasper. Hardyston of the arkosic type, quartz, and flint are present. Some of the limestone is slightly silicified. Yellow clay occurs in the banks.

249. This pit is several hundred feet long and filled with water. Most of the sides are covered by trees and brush, but they show some yellow clay, and pyritic material which is mixed with clay and gives off the odor of sulphur when broken. Limestone fragments, sericitic material, lump and fragmental ore, flint, and quartz containing limonitic material occur here. Several small dumps at one end of the pit show some jaspery material and Hardyston sandstone.

250. This mine has been completely filled.

251. This large mine hole is filled with water and the sides and surrounding dumps are grass-grown. Yellow clay, lump and fragmental ore of the bombshell type, limestone, jasper, and a little quartz containing limonitic material occur on the banks. There is sericitic material and white clay on the dump.

252. Robert McIntire's mine.

"This mine has long been abandoned and is grass-grown so that nothing can be seen."

This mine consists of several small pits which are completely covered by trees, brush, and grass.

253. This mine has been filled in.

254. Consists of three pits. The largest and most southerly one has water and a small island of yellow clay in the eastern end; the other part of the bottom is grass-grown. The banks are covered by trees and brush. The northwest pit is long, narrow, and partly filled with water. Its banks also are covered by trees and brush. The third pit is rather large and filled with water. Several large dumps to the east are grass-grown. These mine holes have the same minerals as mine 251.

255. J. Spinner's mine.

> "Not worked when visited and no ore in sight, the sides being much washed. The pit is a small one."

This small pit is being used as a dump. A shaft 130 feet deep was dug here, but it has been filled in. Considerable gneiss and siliceous material, and several large boulders of lump ore are here.

256. This mine has been completely filled.

257. P. Miller's mine.

> "The two excavations at this place are not worked and so much washed, that nothing could be made out as to the character of the deposit."

These two pits have been filled.

258. The middle one of three large pits is filled with water and all the sides are covered by trees and brush but show some yellow clay, quartz, limestone fragments, flint, and lump and fragmental ore. The eastern pit is the largest and is grass-grown.

259. This limonite mine is about two miles east of Zionsville. The opening is irregular, about 200 feet long, 50 feet wide, and about 20 feet deep. Great irregular blocks of jasperoid up to 10 feet in diameter are strewn about, and smaller amounts of normal Hardyston sandstone, some pieces containing arkose. The history of this mine could not be obtained.

259a. Henry Hoch's mine.—The first ore hauled to the furnace of the Crane Iron Co. at Catasauqua came from this mine. It was worked at intervals from 1840 to 1908. It is an open pit mine about 300 feet long, 200 feet wide, and 75 feet deep. The ore was unusually red in color, owing to the presence of much goethite, and averaged about 43 percent iron. An analysis made October 30, 1890, by the Crane Iron Co. of high-grade ore is as follows:

Fe	48.308	SiO_2	11.850
P	.340	Al_2O_3	2.927
S	trace	MgO	trace

The ore was regularly distributed through the clay in the form of large masses, which could be picked from the clay by hand, and also as small pieces called "wash ore," which were obtained by passing through a long washer.

Fairly complete statistics of production except for the last few years the mine was worked, have been obtained from the books of the Crane Iron Co., which used practically all the ore. The annual production, according to these statistics, ranged from 24 tons in 1860 to 4,073 tons in 1840. The total production from 1840 to 1898 was 29,129 tons.

259b, 259c, 259d. No information concerning these three small mines.

260. Limonite ore has been dug near the contact of the Hardyston sandstone and the gneiss about 1¼ miles east of Shimerville.

261. Snyder's mine is about 1¼ miles west by south of Old Zionsville. It was worked for two years by the Thomas Iron Co. The shaft is said to have been 125 feet deep. Drifts were run east and west

parallel to the valley. Caved ground west of the shaft indicates the position of a drift. The association of limonite ore and much chalcedony and the absence of sericitic material indicate that the ore lies within the Hardyston. Pieces of dense Hardyston sandstone and arkosic sandstone were picked up near-by.

ANALYSES OF THE LIMONITE ORES

The following analyses made by the Second Geological Survey of Pennsylvania * have been tabulated to show the great variation in the four principal constituents of the brown hematite ores. The first chart gives the analysis of the "mountain" ore in the Hardyston sandstone and jasper ores; the second chart gives the analysis of the "valley" ores in the limestone.

A comparison of these analyses will show that it is not possible to differentiate absolutely between these two types of ore. In general the iron content is lower and the silica higher in the "mountain" ore, which is natural because of the association with Hardyston sandstone and jasper. The percentage of iron in the "mountain" ore ranges from 30.1 in mine 195 to 47.2 in mine 194. The "valley" ores range from 58.5 in mine 182 down to 26.4 in mine 10. Although the spread is larger in these ores, most of them analyze about 43 to 50 percent iron. Some of the ores may analyze as high as 75 to 80 percent silica. These contain much jasper and quartz. Material of this sort was discarded. The "insoluble residue" is almost entirely silica.

The sulphur content of both types of ores varies little and is under 0.3 percent with the exception of one or two mines where there was considerable pyrite. The phosphorus content also varies little and, although high for iron, is less than 1.0 percent in all but a few mines. The quantity of manganese in both these types of ores is much higher than that of sulphur or phosphorus. In mine 10 the ore contained 17.648 percent manganese, due to a fairly thick bed of manganese ore in the mine. In general the "mountain ore" contains somewhat more manganese than the "valley ore," although the collected analyses scarcely indicate it.

Analyses of "mountain" iron ores

Sample	Fe	Mn	S	P	Insoluble residue
1	30.10	0.589	.062	.299	43.035
2	34.00	0.115	.020	.676	37.695
3	36.50	1.325	.107	.547	31.215
4	37.00	3.033	.035	.186	28.990
5	39.25	5.512	.029	.149	21.880
6	44.60	0.576	trace	.151	20.340
7	45.20	2.132	.026	.657	12.780
8	47.20	2.709	.039	.075	14.980

1. Henry Kline's mine, 195. Lump ore.
2. Schwarz's mine, 178. Lump ore.
3. Trexler and Kline's mine, 190. Lump ore.
4. Harry Kaiser's mine, 93. Lump and fine ore.
5. Keck and Ritter's mine, 201. Lump ore.
6. Thomas Iron Co.'s mine, 91. Limonite, hard and compact.
7. Elias Daney's mine, 177. Lump ore.
8. Jesse Kline's mine, 194. Lump ore.

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* Report M, 1875, pp. 48-55; Report MM, 1879, pp. 211-219.

Analyses of "valley" iron ores

Sample	Fe	Mn	S	P	Insoluble residue
1	39.30	0.065	.008	1.269	28.195
2	47.70	2.968	.049	0.328	12.595
3	50.00	0.208	.080	0.068	12.520
4	47.00	0.641	.053	0.061	15.770
5	26.40	17.648	.010	0.095	21.860
6	53.00	0.216	.024	0.096	7.290
7	32.70	0.374	.030	0.179	39.050
8	46.60	0.454	.027	0.597	16.230
9	45.30	0.749	.032	0.137	21.060
10	46.50	0.590	.022	0.128	16.300
11	47.00	0.518	.030	0.111	16.050
12	51.25	0.381	.016	0.100	11.010
13	43.00	4.575	.049	0.109	19,060
14	51.95	0.360	trace	0.106	11.430
15	48.50	0.194	trace	0.123	16.560
16	48.00	0.173	.032	0.120	15.950
17	38.00	1.484	.020	0.108	30.970
18	48.25	0.432	.045	0.025	18.450
19	42.30	0.648	.026	0.100	24.120
20	48.20	0.418	.005	0.158	14.810
21	48.10	0.360	.045	0.164	13.440
22	57.50	0.749	trace	0.165	3.470
23	58.50	0.223	.084	0.043	2.800

1. J. Ritter's mine, 3, at Ironton. Limonite, compact and flaggy and forming a vein in the Utica shale.
2. Same mine as 1.
3. P. Brown's mine, 4, at Ironton. Lump ore.
4. Same as 3.
5. Ironton Railroad Co.'s mine, 10, at Ironton. Lump and wash ore. Compact, botryoidal; also stalactitic, general structure somewhat flaggy.
6. John Roth's mine, 158. Lump ore.
7. Jonas Kreischman's mine, 105. Vein ore.
8. Jonas Kreischman's mine, 104. Wash ore.
9. Wiand's mine, 172. Sandy limonite with considerable fine quartz in the ore.
10. P. Marck's mine, 173. Limonite, arenaceous, hard and compact.
11. J. Barber and Co.'s mine, 83a. Limonite, compact with large mass of fibrous ore.
12. Ludwig's Old mine, 96. Limonite, hard, arenaceous with broken concretions of pipe ore.
13. Blank's mine, 99. Limonite, compact, arenaceous, containing cavities lined with goethite and lepidocrocite.
14. Reuben Romig's mine, 134. Limonite, compact and cellular with considerable admixture of yellow clay.
15. Werner and Reinhart's mine, 132. Limonite, hard, arenaceous, compact and cellular with an admixture of yellow clay.
16. Same as 15.
17. Milton Lauer's mine, 133. Limonite, hard, compact and very sandy.
18. Frank S. Lichtenwallner's mine, 121. Limonite, compact with nodular concretions and small seams of ocherous iron ore.
19. Elwyn Bastian's mine, 152. Limonite, hard, compact, sandy and with considerable quartz in the fine ore.
20. Francis Guth's mine, 153. Limonite, hard, compact, and sandy.
21. Francis Breinig's mine, 68. Limonite, siliceous, and spongy.
22. Oliver Moser's mine, 183. Limonite, compact mass of pipe ore, somewhat cellular, cells partly filled with yellow clay.
23. Thomas Breinig's mine, 182. Limonite very compact, somewhat cellular and stalactitic.

Analyses of "valley" iron ores

Sample	Fe	Mn	S	P	Insoluble residue
24	45.70	0.648	.034	0.157	20.210
25	48.50	0.360	.002	0.328	15.580
26	51.75	0.309	trace	0.270	10.350
27	49.30	0.216	trace	0.235	15.120
28	46.60	0.144	trace	0.276	19.880
29	49.00	0.187	trace	0.172	15.400
30	51.70	trace	.214	0.066	10.500
31	45.00	0.626	trace	0.190	21.900
32	28.10	5.029	.002	0.551	36.430
33	51.40	0.259	.021	0.233	11.290
34	47.00	7.464	.003	0.630	4.940
35	36.50	2.932	.031	3.135	18.900
36	49.60	0.538	.007	1.288	9.440
37	43.70	0.763	.005	0.869	18.580
38	42.80	0.252	.036	0.222	25.040
39	50.40	1.203	.002	0.993	10.050
40	41.20	0.028	.191	0.056	25.945
41	51.30	0.064	.106	0.192	9.145
42	40.00	0.115	.140	0.099	26.860
43	41.00	0.036	.098	0.240	26.735

24. Nathan Whitely's mine, 180. Limonite, hard, arenaceous, structure flaggy, some of the pieces decidedly fibrous.
25. William B. Fogel's mine, 140. Limonite, hard, compact, arenaceous with somewhat of a laminated structure and considerable admixture of yellow clay.
26. Henry Swartz and W. B. Fogel's mine, 139. Limonite, sandy and containing small cavities lined with goethite.
27. Alwyn Bortz's mine, 143. Limonite, compact and argillaceous with considerable admixture of ocherous earth.
28. Alwyn Bortz and William Koch's mine, 144. Limonite, cellular and somewhat nodular; of a dark brown color.
29. Jonas Grammis's mine, 146. Limonite, soft and cellular with some cells filled with yellow clay, partly laminated structure.
30. Gackenbach's mine, 148. Limonite: stalactitic, cellular, sandy; color is various shades of brown and vermillion.
31. Francis Fisher's mine, 154. Limonite, arenaceous; exceedingly hard and tough with nodular concretions and velvety surface.
32. J. & D. Smith's mine, 67. Limonite, compact and exceedingly sandy with considerable adhering yellow clay. Color is various shades of light and dark brown.
33. Charles Miller's mine, 64. Limonite, arenaceous with a large admixture of ocherous iron ore.
34. J. D. Scholl & Co.'s mine, 65. Limonite, compact and cellular with numerous seams of ocherous earth.
35. Jacob Steininger's mine, 61. Limonite, compact and arenaceous with considerable admixture of ferruginous clay.
36. Henry Stein's mine, 58. Limonite, rather compact with considerable coating of white clay; some pieces of a brick red, and others of a foxy color.
37. Jesse Laros' mine, 56. Limonite, compact and arenaceous; of a very dark color.
38. Levi Lichtenwallner's mine, 54. Limonite, hard and sandy with considerable ocherous iron ore.
39. Kraemlich & Lichtenwallner's mine, 53. Limonite, hard and cellular; pieces generally of a slaty structure. Colors are a dark brown and cinnamon brown.
40. John Heninger's mine, 29. Wash ore. Compact, arenaceous with considerable adhering clay. Color is various shades of brown and vermillion.
41. Hiram Boyer's mine, 35. Wash ore. Cellular, stalactitic, and argillaceous.
42. Daniel Levan's mine, 30. Wash ore. Arenaceous and cellular with the cells carrying considerable clay.
43. Calvin Guth's mine, 40. Arenaceous and cellular, some fine-grained and flaggy. Color is various shades of brown and vermillion.

Analyses of "valley" iron ores

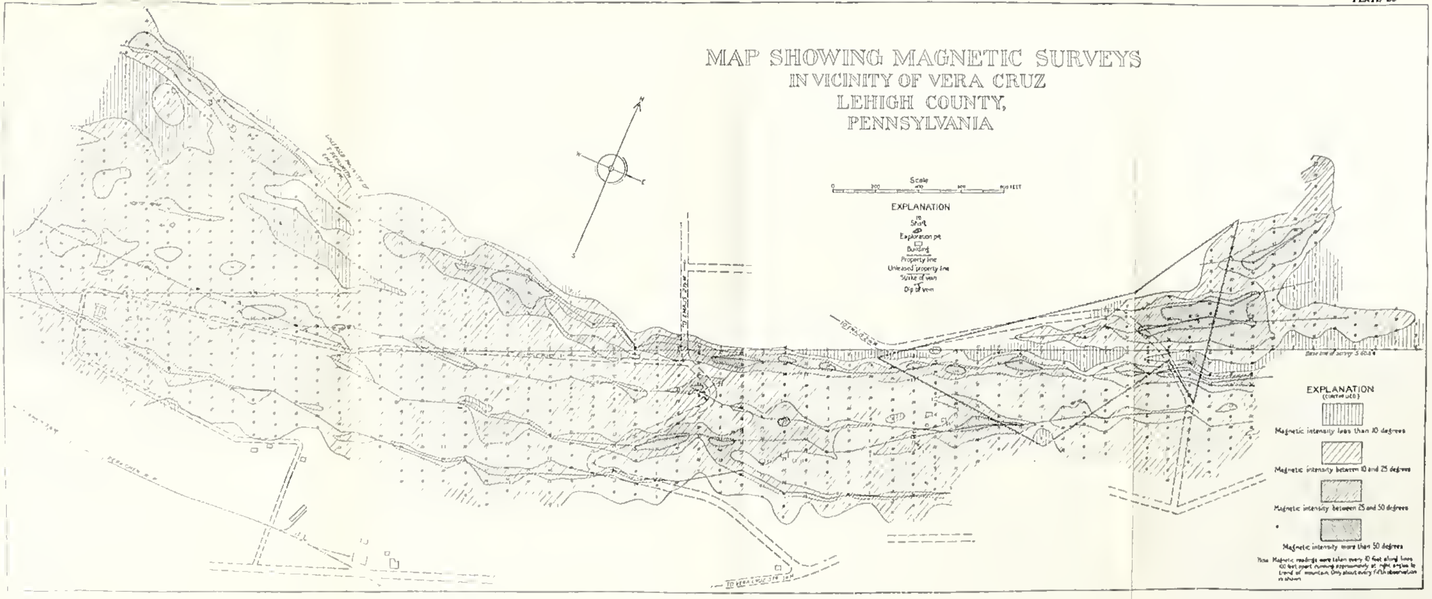
Sample	Fe	Mn	S	P	Insoluble residue
44	44.20	0.036	.043	0.760	20.315
45	43.90	0.165	.038	0.164	21.860
46	46.00	0.050	.073	0.210	17.870
47	46.30	0.201	.033	0.264	17.500
48	32.50	0.338	.038	0.168	42.370
49	49.50	0.194	.019	0.102	13.410
50	46.30	0.475	.018	0.160	15.290
51	40.60	0.027	.393	0.544	25.460

44. Benjamin Weaver's mine, 48. Lump and wash ore. Compact, brittle, and a dark brown color. Fine ore carries considerable clay.
45. James Kline's mine, 47. Lump and wash ore. Compact, flaggy, and arenaceous with considerable yellow, white, and pink-tinted clay.
46. Scheirer's mine, 14. Lump and wash ore. Compact, arenaceous and cellular. Color varies from dark brown to a reddish brown.
47. Ruch & Brother's mine, 13. Lump and wash ore. Cellular and botryoidal with considerable clay. Wash ore carries a good deal of quartz.
48. Jonas Biery's mine, 18. Exceedingly sandy; somewhat cellular with considerable free quartz and clay.
49. Charles Glick's mine, 156. Lump ore. Compact, also cellular with considerable adhering clay. Color is a dark brown.
50. H. & F. Jobst's mine, 166. Wash ore, rather compact and shelly with a large amount of clay.
51. Samuel Sieger's mine, 51. Lump and wash ore, arenaceous and cellular; many cells filled with clay. Some of the ore is compact and fine-grained with a flaggy structure. Wash ore carries considerable quartz.

Magnetite Ores

Distribution.—Magnetite is widely distributed throughout the pre-Cambrian gneisses of Lehigh County as a rather abundant rock-forming mineral. Locally, it is segregated as iron ore, and can be picked up as float rock in hundreds of places on South Mountain. There are scores of shallow pits in the mountains where prospectors have tried to locate veins of magnetite ore, and specimens about these openings commonly indicate the presence of some good ore, though it may be of no commercial importance. After heavy rains patches of magnetite sand derived from magnetite-bearing rocks or magnetite veins are commonly seen in the gullies on the lower slopes of the mountains that are composed of gneiss. Sand of this character is especially abundant along the base of the mountain between Colesville and Vera Cruz. Careful exploration by means of magnetic surveys and the digging of trenches or shallow shafts may determine the location of other veins of magnetite as valuable as those that have been worked.

Reports are current that magnetite mines were operated in numerous places in the county about which at present no data can be obtained, but as far as can be ascertained the locations shown on the map are the only places where there has been any mining of consequence. By far the most productive region is that extending for 1½ miles along the south side of South Mountain north of Vera Cruz Station. The mines there have produced about 300,000 tons of ore



MAP SHOWING MAGNETIC SURVEYS
IN VICINITY OF VERA CRUZ
LEHIGH COUNTY,
PENNSYLVANIA

Note. Magnetic readings were taken every 10 feet along lines 100 feet apart running approximately at right angles to trend of mountain. Only about every fifth observation is shown.

and are by no means exhausted. One of them was reopened and worked for a short time during the first World War.

Since there is so little information concerning the individual magnetite mines of the county and they are much alike, the general descriptions are mainly replaced by descriptions of the Vera Cruz locality.

History.—The following note from Mathews and Hungerford's History of the Counties of Lehigh and Carbon published in 1884 furnishes a few facts of historical interest. "On the east (south) side of the same mountain (South Mountain) there was discovered, about the year 1848, several very rich magnetic iron-ore veins. Those on the premises of William Brunner, Henry Wickert, and others have been operated by David Lewis (the oldest ironmaster of Lehigh County), F. T. Jobst and George Neumoyer. The Hellertown Iron Co., Lewis, Pascoe and Webb, Schwarz, Dickenshied & Co. took in 1880 a lease on the premises of F. T. Jobst (formerly of William Brunner), and continued the operation of the mines. They discovered some rich veins of ore from two to twelve feet thick, and delivered an average of five thousand tons per year. Several other mines along the mountain, on the premises of Daniel Klein, Joshua Fry, and others, have been kept in operation." (p. 346.)

Occurrence.—The ore of the Vera Cruz region occurs in tabular bodies, generally called veins, which have a maximum width of 15 feet and dip to the south or southeast at angles of 45° to 55° and strike approximately east. The veins do not maintain a uniform thickness in any of the mines, but narrow and widen along both the dip and the strike and in places pinch out altogether. In most places the veins are parallel to the bands in the inclosing gneiss, but in some places they do not maintain this attitude. Though most of the veins are in the lighter-colored gneisses, some are associated with the dark basic gneisses, and the same vein may pass from one kind of gneiss to the other without changing its character, as is well shown near Vera Cruz Station.

In most places the ore body is sharply delimited against the enclosing wall rock, but in some places the transition is so gradual that it becomes difficult to determine the limits of the vein. Veinlets of magnetite that form offshoots from the vein commonly penetrate some distance into the wall rock, which in most places carries some disseminated magnetite. In Jobst's tunnel, northeast of Vera Cruz Station, the wall rock between two veins for a distance of over 250 feet contained from 15 to 25 percent iron.

In the Vera Cruz region, the only place where exact data have been procured, it was long known that three veins, roughly parallel in direction, extended for a considerable distance along the mountain. A magnetic survey of a portion of that region was made about 1899 by The New Jersey and Pennsylvania Concentrating Company that had obtained "options on hundreds of acres of iron ore lands on the Lehigh Mountains." The work was done by Tobias Castelane under the direction of Thomas A. Edison, the president of the company. It was found that seven veins were present, four of which extend for distances of half a mile to 1½ miles. On the magnetic survey map

(Plate 26) two of these veins are seen to unite. The other veins are short and apparently contain little workable ore.

In some of the mines, particularly the Wickert, the vein was offset by a few small faults, but the continuity and parallelism of the major veins indicates little displacement.

The ore continues to the lowest depths reached by mining; in fact, in several mines the ore improved in quality and the veins widened in the lowest levels, and there is little doubt that the ore bodies extend as deep as profitable mining can ever be done.

Character and composition.—The magnetite ores in the region are usually known as the "hard ores" or "rock ores" to distinguish them from the brown (limonite) iron ores. Except near the surface, where weathering has removed the accompanying pyrite and decomposed the feldspar, the ore is compact and hard but so brittle that it breaks readily. Specimens of many different kinds of ore can be obtained, even in a single mine.

The most abundant variety of ore shows somewhat indistinct laminations which differ in the quantity of gangue minerals present. These layers are from a quarter to half an inch in thickness. In some mines considerable ore consists of alternating layers of quartz and magnetite that suggest crustification, such as occurs in veins formed in open fissures. The bands of pure quartz are as much as three-quarters of an inch thick in some places.

The magnetite occurs in some ores as irregular masses, but in most ores it forms in lenses or layers, especially in those ores that consist mainly of quartz and magnetite. Some of the magnetite grains interlocking with the gangue minerals or included within the quartz are clearly older than other particles which form small veinlets that cut across the gangue minerals.

Quartz is by far the most abundant gangue mineral, and much of the ore consists almost exclusively of magnetite and quartz. The quartz is mostly clear and has a slight bluish tint. It occurs as single irregular grains or as lenticular or veinlike bands with a fine granular texture. Many small grains of magnetite are included in the quartz, and in places the quartz is cut by thin bands of pure magnetite.

Feldspars, mainly white or light-green plagioclase but also some orthoclase, are common constituents of the gangue and occur as irregular grains or as slightly elongated lenses or "augen." Pyrite is abundant in places and shows a tendency to form rims about grains of quartz or to occur as thin streaks along joint planes, although irregular grains of it are disseminated throughout much of the ore. Hornblende is an abundant constituent in certain places but is practically absent in most of the ore. Much of the hornblende has altered to chlorite. Coarse hornblende is common in the wall rock. Biotite occurs like hornblende but is somewhat more abundant. Bands in which biotite is the most abundant constituent are common in highly laminated ores, especially in contact with the streaks of fairly pure quartz. Ilmenite can seldom be detected, but some of the analyses show a rather high percentage of titanium.

Analyses of the magnetite ores of the region show approximately the following ranges and averages:

Analyses of magnetite ores of the Vera Cruz region.

	Range	Average
Fe	29.00 to 55.00	42.00
SiO_2	15.00 to 44.00	35.00
P	.03 to 1.528	.054
S	.007 to 1.05	.07
Mn	.00 to .03	.01

The wall rocks in the vicinity of the Vera Cruz ore masses in several occurrences contain considerable magnetite and perhaps average 18 percent iron. Edison had hoped to be able to concentrate profitably both the magnetite of such wall rocks as well as that of the veins and calculated that in the Vera Cruz area mapped magnetically there was about 20,000,000 tons of ore above water level. However, the mill which was erected at Edison, N. J., to concentrate similar New Jersey ores magnetically did not prove a success, and the whole project was abandoned.

Origin.—So much has been written in regard to the origin of the magnetite ores of the pre-Cambrian rocks of the eastern United States that it would be impracticable here to review all the theories that have been proposed. This work has been ably done by W. S. Bayley.*

The light and probably the dark gneisses associated with the magnetite ore bodies are igneous in character. These rocks in the vicinity of the magnetite veins contain much magnetite in the form of disseminated interlocking grains that are certainly of primary origin and were formed when the igneous magma solidified from fusion. Subsequently aqueo-igneous products of differentiation from the subterranean magma, consisting of greater amounts of silica and magnetite and lesser amounts of feldspar and ferromagnesian materials, were intruded within the cooled rocks. These intrusions came up in the form of sheets along roughly parallel lines, owing to stresses or actual breaks in the rocks that were brought about by some force which acted in one direction and weakened the rocks in parallel lines sufficiently for the later magmas to come toward the surface. The materials brought up were probably in solution in gases or highly heated waters, which penetrated the country rock in many places and injected into them additional magnetite to that which they already contained. Many of the country rocks are injection gneisses, as shown by the relation of some of the magnetite to the other minerals, yet it is doubtful whether all the magnetite of the associated gneisses originated in this manner.

The underlying magma continued to differentiate, and during some later period, or perhaps during several periods, earth stresses forced some of the magmas to the surface. As the places of earlier intrusions were the weakest places in the overlying rocks the later solutions came up through the earlier intruded rocks. In the process of differentiation the solutions that came to the surface at times contained almost pure quartz and at other times practically nothing but magnetite, a difference which accounts for the pure veinlike masses of these minerals that are common. In places a vein of magnetite cuts the quartz, but elsewhere the relation is reversed. Some pyrite was also present in some of the aqueo-igneous solutions, and its relation to the other minerals shows that it was formed after most of the minerals of the ore body had solidified.

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* Bayley, W. S., Iron mines and mining in New Jersey: New Jersey Geol. Survey, vol. 7, pp. 147-193, 1910.

As the later intrusions took place the earlier intrusions were enriched by magnetite and quartz, which replaced some of the silicate minerals, such as feldspar, hornblende, and biotite, of the earlier intrusions. There was a tendency for the hornblende and biotite to recrystallize in larger grains adjoining the passageways for the solutions as is shown by many specimens collected in the region.

If this explanation of the origin of the magnetite ores of this county is correct, and it seems to explain the phenomena observed better than any other known theory, the ore bodies owe their origin to ascending aqueo-igneous solutions; hence the ores should continue to great depth without any marked change in either quality or quantity. They surely extend much deeper than it would ever be profitable to mine them.

Methods of mining.—In mining the limonite ores open-cut methods predominated, but in mining the magnetite ores very little open-cut work was practicable. The dipping beds of ore a few feet in thickness which were inclosed in hard rocks necessitated shaft mining almost from the start, although some open-cut mining has been done in the region to the depth of 20 to 25 feet. Most of the shafts were sunk in the veins and were inclined to the south at angles of 45° to 55°. From the shaft, levels were driven to either side and the ore was removed by underhand stoping. In one place a tunnel was driven into the hill to cut the vein of ore 135 feet below the surface. Although the tunnel was serviceable for drainage, it was never used for removing ore, which was hoisted through a vertical shaft to the top of the mountain.

The wall rock in most mines was very firm, so that little timbering was required, even for the shafts. As the depth increased the water became abundant but was not so serious an obstacle as in the limonite mines, because of the location of the magnetite mines higher up on the mountain slopes and the greater solidity of the inclosing rocks. However, in mining limonite some water was required for washing the ore, whereas in the magnetite mines the water was purely a disadvantage.

Some of the ore when brought to the surface was cobbed to remove the leanest materials, but received no further treatment. No mill for the concentration of the low-grade ore was erected. Had a sufficient tonnage been developed no doubt a mill would have been built. It is said that the cost of mining the ore ranged from $3.50 to $4.00 a ton and it was sold for $5 to $6 a ton. Almost all of it was hauled from the mines to nearby furnaces or to the railroad to be shipped.

Most of the mines were operated by the owners, who sold the ore wherever they could. A few mines, however, were controlled by iron companies that owned furnaces and were leased on a royalty with the arrangement that all the ore should be brought to their furnaces and paid for at prevailing market prices. The royalty ranged from 20 to 50 cents a ton.

Economic considerations.—For many years the magnetite mines of the county have been closed, and some of the last ore mined long remained unsold. So far as known, the ore was not exhausted in any of the mines, but instead in some of them was more promising when operations ceased than it had been previously. The present condition seems to be due in part to the small and uncertain output, which was neither large enough nor sufficiently regular to appeal to iron manufacturers, and in part to the quality of the ore in comparison with other ores that are shipped into the district from other iron districts. The large amount of silica in the ore is especially objectionable, and the iron content is considerably lower than that of the Lake Superior, northern New Jersey, or Adirondack ores.

The only hope for the future of magnetite mining in this area seems to be in a change of plans by which the production would be largely increased and concentrating mills erected. The ore could be concentrated magnetically with ease, and the product obtained should find a ready market at the furnaces still in operation in the immediate vicinity. It is not at all improbable that the tailings, which would consist almost entirely of angular quartz particles, might be sold for concrete and road metal for a price sufficient to pay a large part of the cost of concentration. Unless the ore is concentrated by mill processes it is questionable whether any of the magnetite mines of the county can ever be profitably operated.

DESCRIPTIONS OF INDIVIDUAL MAGNETITE MINES

262. The Emaus Iron Ore Co.'s mine, formerly known as the Hildegast or Shelly mine, is on the First or Front vein at the extreme west edge of the Allentown quadrangle north of Vera Cruz. It seems to have been first opened about 1890 for the Coleraine Iron Co. of Redington. It was worked at several different times. It was acquired by the above-named company in 1914 and in 1915 cleaned out and retimbered preparatory to working. All work soon ceased. This mine is the last magnetite iron mine of any kind to be operated in Lehigh County.

The shaft, which was sunk along the vein, is said to have been 100 feet deep and the ore body from 3 to 5 feet thick. The ore, which is of fair quality, contains much clear quartz and small amounts of pyrite, hornblende, and feldspar.

263. The Moyer mine, which is on the third vein, was first worked about 1885. It was last worked by James Hosking about 1897. The shaft is 60 feet deep; drifts have been run about 100 feet both east and west of the shaft. The ore averages about 45 percent iron. It is estimated that the mine has produced about 10,000 tons. The ore and vein are similar to that found in the Wieand mine.

264. The Wieand or Mann mine was worked before the Civil War and is one of the oldest magnetite mines in the region. It has two shafts about 75 feet in depth. The vein is 5 to 6 feet thick. The ore is fine-grained and contains considerable feldspar and mica as well as quartz. Drifts were run about 150 feet both east and west of No. 1 shaft. It has been estimated that the mine has produced approximately 100,000 tons of ore. Much of the ore was shipped to the Crane Iron Co.

265. The Fink mine has a shaft that is said to be 80 feet deep. It is on the Third vein, and the ore is similar to that of the Moyer and Wieand mines. The vein ranges from 4 to 8 feet in width. The mine produced 5,000 to 6,000 tons of ore, which was shipped to the Bethlehem Iron Co.

266. The Wickert mine, which was earlier known as the Bader mine, was opened about 1880. It was last worked by James Hosking in 1910. There are four shafts on the property, two of which are about 200 feet in depth, and several open cuts. Drifts have been run along the vein for a distance of several hundred feet. The vein, which is known as the Second or Back vein, is 5 to 14 feet wide and shows a decided tendency to widen and pinch both along the dip and strike; in places ore was absent. The vein dips about 55° S. and strikes almost due east. Some faulting has offset the vein, making it appear as two veins. In the upper levels the ore averages about 45 percent iron, but in the deeper levels it contains from 50 to 55 percent iron. A sample which had been exposed on the dump for about 20 years was analysed in the laboratory of the Bethlehem Steel Co. with the following results: Fe 37.51, Mn .00, P .023, S .012, SiO_2 33.07. Another sample from this mine analyzed in 1884 yielded 43.21 percent of iron and 35.36 percent of SiO_2.

The ore is mainly a mixture of magnetite and clear quartz, which in places occur in thin alternating bands, but in other places the two minerals are in intimate association in a granular mass.

The method of working was to run drifts along the vein and then stope down on the ore. At one time two shafts were in use in the mine, and for about four years there were about 60 men in the employ of the company. The mine has produced from 60,000 to 65,000 tons of ore. Several hundred tons of ore were left on the dump.

267. At the Swartz mine several open cuts and shafts were opened about 1884. At the depth of 25 feet in one of the shafts which is 55 feet in depth a drift was driven 6 feet to the east and another 15 feet to the west. The mine is located on the First or Front vein, which is here about 5 feet thick and has a seam or "horse" of rock in the center from 6 to 12 inches thick. The ore is fine-grained and contains considerable pyrite. The mine is said to have produced about 3,000 tons of ore, which was shipped to the Bethlehem Iron Co. Two samples from the dumps that were analyzed by the Bethlehem Steel Co. in 1906 gave the following results:

Analyses of magnetite ore from Swartz mine.

Fe	35.00	43.00
Mn	.00	.01
P	.056	.066
S	1.048	.191
SiO_2	38.55	32.00

A shaft sunk on the Third vein just east of a mountain road is now completely filled. It is reported to have been 30 feet in depth. The ore found was leaner than that in neighboring mines.

268. No information available concerning this working.

269. A shaft on the Second or Back vein is on the west side of a road. The material on the dump contains pieces of a very basic gneiss, which seems to have been associated with the ore.

270. The Engelman mine comprises a shaft, which is commonly supposed to be on the Second or Back vein, a short distance west of the Jobst mine. The magnetic survey chart (pl. 26) shows, however, that it is on a slightly different vein but one which unites with the vein worked in Jobst's shaft and tunnel. Little is known of this mine.

271. At the Jobst mine in 1875 a tunnel was run into the hill from the road by the Hellertown Iron Company. At a distance of 150 feet from the entrance a 4-foot body of ore known as the Front or First vein was penetrated and at 411 feet the Second or Back vein was found. The Front vein, which contains solid ore of good quality, was never mined. The Back vein was mined extensively. From the end of the tunnel a shaft was driven upward to the surface, a distance of 135 feet. This shaft was also sunk 75 feet below the tunnel level. The Back vein at the tunnel level was 6 feet thick, but at the bottom of the shaft it was 8 to 15 feet thick and contained solid ore of good quality. Above the tunnel level the vein was only about 2 feet thick, too thin to be worked with profit. The vein dips to the south about 45°. The ore contains considerable hornblende and pyrite.

Tobias Castelane, who investigated the Vera Cruz mines for Thomas A. Edison, sampled the rock in the tunnel between the two veins and found that it contained from 15 to 25 percent iron.

The ore was stoped along the Back vein below the tunnel level to a distance of 300 feet along the strike and hoisted to the surface through the shaft.

About 40,000 tons of ore was produced from this mine, most of which was shipped to the furnaces at Hellertown, Emmaus, and Edgehill.

272. No information is available regarding the Bachman mine.

273. Nothing is known concerning this mine, which was probably only a prospect hole.

274. The Eichelberger & Frey mine is 1 mile west of Spring Valley on the farm owned by W. J. Sleifer. Magnetite ore was mined at this place for several years prior to 1883. There are two shafts, one of which is reported to be 100 feet in depth. About 4,000 tons of ore was mined, most of which was hauled to the Bingen furnace. No data could be obtained in regard to the size and character of the vein. The ore contains much quartz and considerable pyrite, feldspar, and hornblende. The following analyses of ore from the dumps were made by the Bethlehem Steel Co. in 1900 and 1905:

Analyses of magnetite ore from Eichelberger and Frey mine.

	1	2
Fe	54.81	35.47
Mn	.02	.025
P	.04	.029
S	.046	.125
SiO_2	21.28	43.68
Cu	....	.002

There is a report that the ore contained considerable titanium, but this has not been verified.

275. A short distance west of Spring Valley a tunnel was driven into the hill in search of magnetite ore. It is reported that some ore was found but not enough for profitable mining.

276. Prime states that "a small opening has been made for magnetic ore about ½ mile west of Leipert's Gap just west of the mountain summit south of the Shimersville-Emaus road near J. Wetzel's house.

"Nothing can be seen in the opening. Fragments of the ore on the surface are very siliceous. The ore is associated with feldspathic gneiss with hornblende." (Report D3, p. 228.)

277. About 2 miles southwest of Macungie some excavations have been made and considerable gneiss thrown out. It is not certain whether the ore sought and presumably found was magnetite or hematite. A few poor specimens of hematite were picked up. The diggings are close to the Hardyston—gneiss contact so that it is possible they are in the Hardyston and the ore was limonite.

278. John Jacobs' mine. A large waste pile of gneiss near an old shaft said to be 100 feet in depth contains magnetite in lenses or bands in a light to dark-colored gneiss, and grains of magnetite intermingled with feldspar, quartz, hornblende, and biotite. A caved spot west of the dump indicates that drifting was done in that direction. There are indications of an old adit or tunnel at a lower level, evidently driven to intersect the ore body and for drainage. The history of the operation has not been obtained.

279. Joseph Hensinger's magnetite mine. Considerable work has been done here, but no information was obtained regarding the ore body or the character and extent of the operation. The magnetite occurs in the form typical of the magnetite ores of the region.

280. Magnetite mine of Morris Shankweiler. This is similar to 279.

280½. Some magnetite ore was mined near the crest of the large hill about a mile northeast of Old Zionsville. Appears to have been little more than a prospect.

Hematite Iron Ores

Hematite mines were once worked in the vicinity of Old Zionsville and Shimerville, but it has not been possible to obtain much information concerning them. The mines have caved in and there are no outcropping rocks. In Mathews and Hungerford's "History of the Counties of Lehigh and Carbon," published in 1884, is the following description:

"About the year 1870 there was discovered on the premises of Andrew Mechling (now deceased), in Zionsville, Upper Milford, one of the richest magnetite (Prime says specular hematite) iron-ore veins in Lehigh County. It was worked by John S. Schreiber & Co. for about seven years, and since 1878 has been operated by the Crane Iron Company. About the year 1875 there was also a rich vein of the same ore discovered on the premises of Charles Schoenly at the same place; and about the year 1881 there was

> another rich vein of the same ore discovered on the premises of Mr. Gackenbach at the same place, and also on the premises of Jonas Kern.
>
> "All these mines are now carried on by the Crane Iron Company. The ore produces an average of forty-five per cent clear iron.
>
> "On the premises of Mr. Schulz, in Shimersville, is one of the richest veins of oxide iron ore ever discovered in Lehigh County. It produces an average of fifty per cent of iron." (p. 346.)

On the map two localities (281 and 282) have been designated. At the former place a continuous line of old waste heaps and caved ground extends for about one-quarter of a mile. At the latter place a large excavation now filled with water appears much like the old limonite mines in the limestone or Hardyston sandstone. No specimens of ore were found about the pit, only fragments of gneiss.

It is probable that the ores in the Old Zionsville-Shimerville region are similar to some hematite ores that have been worked in Berks and Lancaster counties. Several different mines seem to have been opened here, but at present the location of each is not determinable. On Sheet VII of the topographic map of the Durham and Reading Hills published by the Second Geological Survey in 1883 operations of the "L.V.I.Co." and "G. Schell Ore Mines" are located west of Shimersville and "Mine, Crane I. Co." to the northeast.

Prime (Report D3 pp. 218-219) gives the following brief description:

> One quarter of a mile south of the toll-gate on the Millerstown-Shimersville pike specular iron ore was mined by Geo. Knaus in 1881.
>
> The mine is located between the toll-gate and W. Foster's house on the west side of the pike.
>
> The ore appears to be interbedded with quartzose felspathic rock and the ore is mixed with quartz. About four feet of ore is exposed. The dip is S.50°E.75°.
>
> Riegel's red hematite (specular) ore mine is located a few rods southwest of the hotel at Shimersville on the west side of the pike. The ore lies in a bed varying in thickness from two to six feet. The workings are about 120 feet in depth. Decomposed felspathic gneiss (granulite) forms the foot wall of the ore. The hanging wall consists of decomposed chloritic slate.
>
> The felspathic rock is so thoroughly decomposed that it is easily crumbled in the hand. The bed dips S.70°E.45°-55°.
>
> Schoenley's mine (Crane Iron Co.'s mine) is located a few rods southwest of the toll-gate at Zionsville.
>
> The ore is specular and rests on decomposed felspathic gneiss. Decomposed chloritic slate overlies the ore.
>
> About four feet of ore is exposed in the mine at present.
>
> The rock and ore are easily removed with a pick. The felspathic rock is usually much decomposed and quite soft. The shaft is at a depth of 113 feet. The dip of the ore bed is N.25°W.45°.
>
> Gackenbach and Kern's mine (Crane Iron Co.) is located a few rods east of the toll-gate at Zionsville.
>
> The ore is the specular or red hematite. The felspathic rock adjoining (underlying) the ore is thoroughly decomposed.
>
> The workings are at a depth of 145 feet. The thickness of the bed varies from five to fifteen feet. The bed dips S.15°W.50°-55°.
>
> G. Schell's mine is located about 1/3 mile south-west of Zionsville. The mine is located on the same bed which is developed at Zionsville, (Schoenley's and Gackenbach and Kern's mines).
>
> The ore as well as the associated rock is the same as found at Zionsville.

A little additional information is given in the "History of Lehigh County, Pennsylvania," vol. 1, p. 783 (1914) as follows:

> Eastward of the (Old Zionsville) hotel, on the properties of James J. Gackenbach, Charles Schoenly and Jonas Kern, mining operations were carried on by the Crane Iron Company from 1880 for a number of years, and many thousands of tons were removed. Several shafts were sunk to reach the beds of ore, the deepest having been 235 feet.
>
> To the westward on the property of Anthony Mechling, operations for iron-ore had started ten years earlier, and shafts were also sunk to reach the ore to the depth of a hundred feet.

Iron Carbonate (Siderite) Ores

Considerable iron carbonate ore is present in the lower workings of many of the limonite mines in both the "valley" and "mountain" ores. Its occurrence and origin have been already discussed. It is well, however, to call attention specifically to the importance of this class of ore, for it has been ignored by many persons who have studied the limonite deposits of the Appalachian region. It has been found in almost every place where mining has been carried on within recent years and exposures are good.

The iron carbonate ore is gray and occurs mainly as extremely dense, tough, rounded concretions, the largest of which are 6 inches in diameter. Bombshell carbonate ore in which the cavity is filled with white clay also is common. On exposure to the air the ore changes to limonite and the nodules or bombshells readily crumble.

Most of the carbonate ore as mined was associated with so much limonite that it was shipped as ordinary ore. A few mines, however, made occasional shipments of carbonate ore.

In the Ironton limonite mines, iron carbonate nodules or concretions were not uncommon. The occurrences are described in the descriptions of limonite mines 5, 6 and 7 on previous pages of this report.

83. This is also a limonite ore mine in which iron carbonate was present. The description is given on a previous page. The ore "is hard and compact, surface white, brownish color on fresh fracture, laminated structure, and minutely crystallized."

Analysis of iron carbonate (siderite) ore from mine 83.

(By A. S. McCreath)

Ferrous oxide	36.35% Fe	45.064	Carbonic acid	29.330
Ferric oxide		1.553	Phosphoric acid	0.142
Bisulphide of iron		0.457	Sulphuric acid	0.061
Oxide of manganese		1.150	Water	0.420
Alumina		1.643	Insoluble residue	17.575
Lime		0.644		
Magnesia		1.495		99.534

ZINC

The most important zinc deposits in Pennsylvania are at Friedensville, (Plate 27), in the Saucon Valley, three miles south of Bethlehem. They have yielded large quantities of high-grade zinc ore in the past and may again become an important factor in the zinc production of the country, although the mines are not operating now. Zinc ore has been found in paying quantity only in a very restricted area at and northwest from Friedensville.

Published reports.—Many articles descriptive of the Friedensville deposits, the mines, and the furnaces have been published. The general bibliography in another part of this volume shows such articles published in 1850, 1853, 1854, 1855, 1857, 1858, 1860, 1871, 1872, 1876, 1877, 1878, 1883, 1884, 1885, 1886, 1887, 1889, 1890, 1892, 1893, 1911, 1913, 1914, 1917, 1922, 1924, 1925, 1931, 1935, 1936, and 1939. Some of these are little more than worked-over material, but all should be examined by any one making a thorough investigation.

History of mining operations

Early in the nineteenth century an unusual mineral was found in the soil on the farm of Jacob Ueberroth, half a mile north of Friedensville, but as iron was the only economic mineral known to occur in the region, little attention was given to this strange material. However, about 1830 a wagon-load of the unknown substance was hauled to the Mary Ann iron furnace in Berks County to be tested. Naturally the experiment yielded no metal, as the zinc was all volatilized and escaped.

In 1845 Andrew Wittman, after studying Overman's Metallurgy, experimented with the ore by means of a small crucible in a stove and obtained a few globules of metallic zinc.

In the same year (1845) reports were current of the discovery of gold in the vicinity. Ueberroth therefore suspected that this unknown mineral might be a gold mineral. He took a few pieces to William Theodore Roepper, a local mineralogist who later became the first professor of mineralogy and geology in Lehigh University (1866-1869, Curator of Museum 1866-1871). Roepper experimented with the material in Lehman's foundry, Bethlehem, and proved it to be a zinc ore by making brass from the calamine and native copper.

Roepper induced Robert Earp, a Philadelphia importer, to examine the deposit and obtain a lease on the Ueberroth farm. This being done, Earp mined nine tons of the ore, which was shipped to England in one of Earp's vessels in January 1846. The temperature of the English furnaces being gauged for roasted ore was not high enough for the calamine, so the report came back that the ore could not be used.

Earp and Roepper decided that they did not care to invest their money in further experimentation and offered their lease to the New Jersey Zinc Co. The company turned down the proposition, but the superintendent, Samuel Wetherill, and George Gilbert, decided to take up the offer. Wetherill, a paint manufacturer, in connection with his business, had been carrying on experiments for making zinc oxide from calamine ore and had received a patent for a new process. On obtaining possession of the Ueberroth zinc deposit, he came to Bethlehem and began the erection of zinc oxide furnaces.

The furnaces were located on the south side of the Lehigh River in a community known as Augusta, which later became a part of South Bethlehem. The choice of the site proved to be a fortunate one since, only a few years later, two railroads were built close to the plant, one on each side, the one furnishing direct connection with New York and the other with Philadelphia. The furnaces, with a capacity of 2,000 tons per annum, were completed October 12, 1853, and on the following day zinc oxide was produced from the Friedensville ore by Wetherill's "furnaces" and "tower" processes, combined with Richard Jones' "bag" process of collecting. This process was described by M. S. Henry in 1860, as follows:

> The entire process of manufacture practised here consists, in effect, of the following operations, viz.:—
>
> The ore, pulverized and mixed with coal, is strongly heated in furnaces which are fully supplied with air; the metallic zinc which is thereby extracted in the form of vapor, is instantly oxidized, and the oxide of zinc thus formed, being an exceedingly light powder, is carried immediately from the furnaces by a strong artificial draft, together with large quantities of gases, and such ashes, etc., as are light enough to float in a current of air. These ashes are taken first and separated and deposited with the coarser particles of zinc oxide in rooms provided for the purpose; a part of the pure zinc oxide is afterward caught in chambers, and finally the gases are all strained out by an immense appartus of flannel and muslin bags, to the inner surface of which the last and finest of the zinc oxide adheres, whence it is removed at proper intervals.
>
> The zinc oxide which is thus collected in the chambers and bags, is in the form of a very white, fine, and flocculent powder, which is compressed by proper apparatus into much smaller bulk, and is then carefully packed into strong, tight, paper-lined casks.

The manufacture of zinc oxide from the Friedensville ore was the second successful attempt of the kind in the United States. In 1852 the New Jersey Zinc Co. in their works at Newark, N. J., had begun the manufacture of zinc oxide on a commercial scale. Their output for 1852 was 1,083 tons, and for 1853 it was 1,805 tons,—altogether only about 2,500 tons had been produced in the country before the beginning of operations at Friedensville.

On May 2, 1855, by an act of the Legislature, the Pennsylvania & Lehigh Zinc Co., with a capitalization of $1,000,000, and composed of the same men who had already begun operations, was incorporated "for the purpose of mining zinc ore in the counties of Lehigh and Northampton, of manufacturing zinc paint, metallic zinc, and other articles from said ore, and of vending the same."

Attempts to produce spelter were early made, and between 1854 and 1859 Wetherill carried on a series of experiments for that purpose. He succeeded in producing spelter but the process he developed was not economical and the experiments were discontinued. His method was to heat the ore in the open furnace and then draw the vaporized oxide through incandescent anthracite to reduce the oxide. He made a few tons in this way.

In 1857 Matthiessen and Hegeler, two young men fresh from the School of Mines of Freiberg, Saxony, obtained permission to experiment in the plant which the company had erected at Friedensville. They were successful in making spelter but were not able to make satisfactory terms with the company for the erection of a plant of practicable size. The low price of zinc oxide about this time and the reduced market may have influenced the decision.

In 1859 Joseph Wharton leased the furnaces and began the erection of spelter works of the Belgian type, with retorts made of materials that had been found to be sufficiently refractory. He brought to this country Louis de Gée, of Ougreé, Province of Liége, Belgium, to superintendent their construction. Other Belgians came with De Gée and they were followed by still others in succeeding years. The Belgian furnaces proved to be successful and in July 1859 began producing spelter.

During this time the ore was hauled from the mines to the Bethlehem furnaces by wagon or, in case of unusually bad roads, carried by pack mules.

It is interesting to recall that up to this time spelter had been made commercially at only one place in the country. In 1838, at the United States arsenal in Washington, the first brass was produced in this country. It was made from the zincite ore found at Franklin Furnace and Stirling Hill, N. J., and ore from Perkiomen, Pa., and was used in the manufacture of the standard weights and measures for the U. S. Customs Department. The method was the one known for hundreds of years of producing brass from zinc ore and native copper. The process, however, was so expensive that it was many years before any other attempts were made to utilize the zinc ores of this country. The industry did not meet with much success for several years because the oxide of iron in the franklinite of the ore formed a fusible silicate with the siliceous matter of the clay.

Experiments in making metallic zinc from New Jersey ores were commercially unsuccessful until 1865 when a small regular production began at Newark, New Jersey using refuse zinc oxide. In 1866 the first spelter was successfully made from willemite ore. The first really successfully spelter furnace, using New Jersey ore, was built in 1869 at Jersey City by the Passaic Zinc Company. Thus the production of spelter from the Friedensville ores in the furnaces erected at South Bethlehem were the first entirely successful zinc furnaces in the United States.

On February 16, 1860, by an act of the Legislature, the name of the company was changed to the Lehigh Zinc Company, by which it is best known. There was much litigation concerning the ownership of the property until 1861, when the company purchased the land outright.

In 1864 and 1865 the company erected a mill for rolling sheet zinc with a capacity of 3,000 casks or 1,680 tons per year. The mill started operations in April 1865.

From 1853 to 1876 the parent company continued to operate its Friedensville mines without interruption. From the beginning of operations until 1875 this company was the only one operating in the district. It, however, never owned the property of the Jacob Correll estate lying just west of the Friedensville church. This property was originally leased by the Passaic Zinc Co., by whom it was sublet to the Lehigh Zinc Co. on high royalties. In 1875, this lease expiring, the Bergen Point Zinc Co. of Bergen Point, N. J., obtained the lease and began operations. For about a year, therefore, until the closing of the Lehigh Zinc Co.'s operations, two companies were at work in the region. The Bergen Point Zinc Co. continued to operate until 1881. The mine has been called the Correll and also the Saucon.

In 1881 Franklin Osgood, who already owned an interest in the Correll mine, purchased the Lehigh Zinc Co.'s property, consisting of the Ueberroth, Old Hartman, and New Hartman mines, and organized the Friedensville Zinc Co. New smelters were erected at the Ueberroth mine and oxide furnaces at the Old Hartman mine. However, from 1881 to 1885 the ores were mainly shipped to Bergen Point, N. J., but after March, 1886, were smelted at Friedensville.

Mining operations at the Correll and New Hartman mines continued with few interruptions to November 1893, since which time the mines have all been idle. The Ueberroth mine was worked for a while in 1883 and again for a short time in 1886. The big pump of this mine was run from September 29, 1890, to September 15, 1891, but merely for the purpose of lowering the water in the Old Hartman mine.

At the present time the New Jersey Zinc Co. owns all the mines that have thus far been opened, with the exception of the Correll mine, together with considerable land adjoining.

In 1914 and 1915 core drilling was done in the region by the New Jersey Zinc Co., and later the New Hartman shaft was retimbered and the new pumps installed. For several months pumping was carried on and the mine unwatered, but conditions brought about by World War I interfered and all work ceased. The most extensive prospecting by both diamond and churn drilling was ended in 1940. Some of the structural results and other features and interpretations have been shown to the writer and are referred to later.

The Correll property was also prospected by two 500-foot diamond drill holes about 1938. Some of these results have been furnished the writer.

Statistics of Production

Satisfactory statistics of production are not obtainable. However, from time to time fragmentary bits of information were published in the mining journals.

From October 1853, to September 1857, the output was 4,725 tons of zinc oxide. In 1865 the production amounted to approximately 3,000 tons of zinc oxide, 3,600 tons of metallic zinc, and 3,000 casks, or 1,680 tons of sheet zinc, representing about one-half the total production of the country. The president of the Lehigh Zinc Co. stated in 1872 that in certain years 17,000 tons of ore were mined and that up to that time, about 300,000 tons had been taken from the ground.

In 1875 the Bergen Point Zinc Co. produced 500 tons of spelter and 1,000 tons of zinc oxide from the ores of the Correll mine. The Lehigh Zinc Co. produced 1,505 tons of spelter from ores obtained from Ueberroth and Hartman mines. From 1876 to 1881 the Correll mine is said to have produced about 50 tons of ore daily. The census statistics for 1880 give a production of 20,459 tons of ore.

In December 1884 the Bergen Point Zinc Co., Bergen Point, N. J., with 8 Belgian furnaces and 888 retorts, had a capacity of 2,000 tons and probably used all or nearly all New Jersey ore. The Lehigh Zinc and Iron Co., with 16 Belgian furnaces and 1,200 retorts, had a capacity of 6,000 tons, and used both New Jersey and Friedensville ores. These furnaces were at South Bethlehem and Friedensville.

Available Information

As nearly 50 years have elapsed since the mines were operated practically all the men concerned have passed away. Published accounts by Clerc, Drinker, and Eyerman furnish nearly all the reliable information available. Clerc was an engineer at the mines for several years and was apparently very familiar with them. Several of the photographs reproduced were furnished by him. Eyerman, a local mineralogist, was the authority on the minerals. Drinker limited his observations mainly to the mines and plants. Even though their descriptions are at variance and slightly repetitious at different places, it seems desirable to present considerable portions of their published articles. The writer's discussions follow these quotations:

Description by F. L. Clerc

The zinc deposits in the Saucon valley, Lehigh county, Pennsylvania, which were once extensively worked, now produce but little ore. Their history, however, has a special interest from their connection with the introduction of speltermaking into this country, and from the fact that they belong to a class of deposits which seems to warrant a belief in their continuance to a considerable depth, and because they are a good illustration of the general effect of the characteristic feature of the ore market above referred to.

Three principal deposits have been discovered, known respectively as the Ueberroth, Hartman and Saucon mines: they occur in magnesian limestone of the Lower Silurian formation, and have many points in common, while they also present some striking differences. They were all at one time owned or controlled by the Lehigh Zinc Company, whose works were at Bethlehem, four miles distant.

The Ueberroth mine, which is, so far as developments have shown, the largest, was worked continuously from 1853 up to the fall of 1876. It was for many years the main dependence of these works, and produced in the neighborhood of 300,000 tons of ore. The strata of limestone are here very much disturbed and tilted up almost to the vertical, apparently by the obtrusion of the syenite ridge of the neighboring South mountain. The ore came close to the surface, and a very rich pocket was found in the clay above and around limestone boulders, which is estimated to have produced 100,000 tons of ore. When this body of ore was exhausted, the ore was followed down in crevices between the boulders. These crevices lie in planes parallel to the bedding of the limestone, or in planes perpendicular to it, and preserve great regularity in their position, and a parallel course for several hundred yards in a northeast and southwest direction; they are nearly vertical, and at the depth of 225 feet, to which the mine was worked, showed no signs of closing up. The ores at first were exclusively calamine and smithsonite; but at greater depth blende made its appearance, coating the walls of the crevices, and in some cases penetrating into them several feet; in other cases, segregated as rich seams, which nearly filled the cross-openings. At first, it was confined to the northeastern end of the mine; but at the lowest depth reached it could be traced almost continuously to the extreme southwestern end. The dip of the orebody appeared to be regular, and to the southwest. Six of these parallel crevices were worked, and about as many crossings; and where they intersected, rich bunches of ore were found, some of which were as much as 60 feet across and 20 feet thick. All the indications seemed to point with increasing certainty to the existence of a backbone or underlying deposit of blende, out of the reach of the action of meteoric waters, from the continuation of which the oxidized ores have been derived.

Timbering the mine was always a serious difficulty, but the greatest obstacle to be overcome was the water. Even at a depth of 40 feet, the flow was already very strong; at the depth of 150 feet, it was found necessary to put in what was then the largest pumping engine in the world. This engine, which is a single cylinder, double-acting, condensing, walking-beam engine, with a pair of fly wheels, has a 110-inch cylinder and a 10-foot stroke, and is calculated to work four 30-inch plunger pumps and four 30-inch lift pumps, with 10-foot stroke, and to take water from a depth of 300 feet. At the time it was stopped, it was running from six to seven strokes a minute, and was working three pairs of 30-inch pumps and one pair of 22-inch pumps, and was easily handling all the water that came to them. The pump-shaft and foundation for the engine were no less remarkable in their way. The latter was built up from the solid rock, 60 feet below the surface of the ground, of hewn blocks of Potsdam sandstone; the former, which measured 30 feet by 20 feet in the clear, was started on a small crevice, and timbered with 12-inch square yellow pine sticks, and divided into three compartments, and further strengthened by two open brattices of the same heavy timber. When the pitch of the vein carried it out of the shaft, the rest of the depth was sunk through solid rock.

The *Hartman mine* distant about half a mile, was worked at first exclusively for calamine. Its exploitation gradually exposed a central horse of blende, which the method of mining adopted made it necessary to leave for the support of the timbers which carried the roof. The increasing importance of this blende at the lowest level worked, 150 feet, caused a change to be made in the method of mining. The mine was operated for a year after the large engine was stopped, and the last work that was done was the putting in of a slope to develop this deposit of blende. The water in the Hartman was always less strong, the pitch of the crevices less steep, and the surrounding rock less disturbed than in the Ueberroth mine; the strike of the crevices was more to the west, and the blende came nearer to the surface. (Plate 28, A.)

The *Saucon* (*Correll*) *mine*, however, affords the simplest and best illustration of this form of deposit. It is distant about a quarter of a mile, and was originally leased by the Passaic Zinc Company, by whom it was sub-let to the Lehigh Zinc Company on high royalties. When the rich deposit of calamine first discovered was apparently exhausted, this sublease was surrendered by the latter company, and in 1875 the original lease passed to the Bergen Point Zinc Company, by whom the mine has been worked ever since. A face of blende was uncovered at the western extremity of the open pit, and the ore followed under a heavy cap of limestone for a distance of 250 feet up to the property of the Lehigh Zinc Company on the west. On this property, it was reached at a depth of 110 feet, under 100 feet of solid limestone, and was followed 150 feet farther on the course of its strike. On both properties, it was followed to a depth of nearly 200 feet. In the fall of 1879, all the property of the Lehigh Zinc Company passed into the hands of its bond-holders under foreclosure of its mortgages, and in the spring of 1880 all the mining property was sold to the proprietors of the Bergen Point Zinc Works.

The workings of these two mines, taken together, show a remarkable regularity of width, pitch and course, and the deposit is clearly shown to be a large chimney or chute of ore of irregular cross-section, which, however, preserves a lenticular shape, the longer axis of which is about 60 feet, and pitches to the south at an angle of about 30 degrees; the transverse axis measures about 30 feet. The axis of the orebody dips to the west-southwest with a slope of about one foot in four. The weathered outcrop has evidently given rise to the pit of oxidized ores and to certain irregular detached deposits which lie in the same course, several hundred yards beyond it.

Here, then, are three similar deposits of zinc ore, with their nearly parallel chimneys of blende and their corresponding beds of calamine, which have evidently been brought up from below, by solution in thermal springs, through crevices formed in the limestone by the gradual upheaval of the neighboring South Mountain, and have undergone subsequent alteration from the action of meteoric waters. Nearer the mountain, where the strata are most tilted and the ground most disturbed, the water is strongest and the largest deposit of calamine is found. In the Hartman mine, the strata are more nearly flat, the blende is sooner met with, and the water is much less strong; and in the Saucon mine, the bleude is met with at the edge of the pit, and only moderate-sized pumps are required in working it at a depth of 200 feet. That the water in these mines comes from the same surface springs which supply the Saucon Creek, is evident from the fact that, when the big mine was abandoned, this creek shrank at once to a small fraction of its former volume, and only gradually recovered it as the mine filled up. Very careful surveys of the bed of this stream failed to discover any point at which it showed any dimunition of its volume or seemed to sink into the ground. It is, therefore, very improbable that the water, having once come to the surface, found its way back into the mine. It was probably tapped in under-ground courses connected with the springs which give rise to the creek. This is the more probable, as the mine which has the most water is on the highest ground and is farthest from the creek, and the mine having the least water is nearest the creek. It is therefore reasonable to suppose that nearly the maximum quantity of water likely to be encountered was already handled, and that, if a solid body of underlying blende were developed, it could be profitably worked with the machinery already in place. The Saucon mine is still the main dependence of the Bergen Point Zinc Works, but its continued working must be attended with increasing cost and uncertain risks.

The ores of this region are remarkably free from lead, arsenic and antimony, and it is this circumstance that gives them their principal value and interest, and has been the basis of the very high reputation of the metal and oxide obtained from them. Only the richest of the ores are, in the present state of the ore market, available as spelter ores, but even the leanest of the oxidized ores produce a very fine quality of oxide. The blende is very peculiar. It is massive, and rarely shows even traces of crystallization; when pure, it has a bluish slate color, has a very characteristic conchoidal fracture, is translucent on thin edges, and gives a clear ring when struck. As generally sent to the works, it resembles broken limestone; is somewhat mixed with iron pyrites, and assays from 35 to 40 per cent of zinc. It is not easy to concentrate, both on account of its non-crystalline structure and of the pyrite it contains.

The causes which led to the extinction of the Lehigh Zinc Company and the abandonment of the first two-named mines were briefly these; the impossibility of competing successfully in the oxide market with the owners of the big mine in Sussex county, New Jersey, after the expiration of the patents covering the oxide process left them free to take the trade, or in the sheet-zinc and metal market with the western smelters, using cheaper and richer ores, at a time when a general depression of all manufacturing enterprises made it unusually burdensome to carry the heavy bonded indebtedness incurred during a period of high prices and general inflation in acquiring mines and putting up machiuery to work them. Under more favorable circumstances, it is probable that these mines could have been profitably worked for years to come; for although the pumping expenses were heavy, they were not excessive, considered as a royalty on the ore, and these charges per ton would diminish in proportion to the amount of ore mined. Now, however, it will probably be left for another generation to discover what value they still have." (F. L. Clerc, 1883.)

Description by J. Eyerman

As the ore (calamine, smithsonite and sphalerite) in this mine (Ueberroth) is near the surface, it is not, at present, difficult to work. The calamine is found in large quantities disseminated through the limestone. It is found mostly on the north side of the mine, where it is worked by a small force of men.

This mine has furnished, and will continue to furnish, the finest specimens of calamine (or silicate of zinc) known to the world. It is very often found in botryoidal and stalactical forms. It is not seldom that sheets or plates of calamine from two to three feet square and from one-eighth to one-fourth of an inch thick, and containing thousands of little crystals on the surface, are found between the crevices of the limestone. Again, it is found as a thin coating to the inside of a quartz geode. This ore is quite scarce at the Eudy mine. It seems to have been replaced by the blende. The smithsonite or carbonate of zinc is found in white scales and in granular masses, coating calamine and blende. It is also commonly found as a brownish earth, which hardens when dry. It is found near the center and along the west side of the mine. It has often been mistaken for clay. This is also mined at present by a small number of men. The sphalerite or zinc-blende is not mined. It is found throughout the mine, with pyrite disseminated through it. It is not met with in as large quantities here as at the Eudy mine. Greenockite (sulphide of cadmium), hydrozincite, and goslarite (sulphate of zinc) are met with in smaller quantities. The sulphate of zinc is scarcely ever found. A considerable quantity of greenockite has been mined. It is found as a yellowish powder coating blende and limestone. It was formerly separated at the Bethlehem works." (J. Eyerman, 1883.)

Description by H. S. Drinker

The mines were originally worked as open cuts, commencing at the outcrop, found by Prof. Röpper. The ore was easily and cheaply extracted so long as it was possible to pursue this system. From twelve to fifteen thousand tons per year were taken out in this way, at a cost of about a dollar per ton. At present, the cost of mining a ton of blende is $6, and a ton of earthy ore $12. About twenty thousand tons of both sorts are mined per year.

Pumping.—The chief difficulty encountered in working these mines is the large amount of water which must be kept under control. In 1854 the open cut of the Ueberroth mine, twenty feet deep, was drained by centrifugal pumps, which were subsequently replaced by a double-acting pump, capable of raising 200 gallons per minute, from a depth of 40 feet. In 1861, a Woodward pump, now in use at the smelting-works of the company, was put up. This was, however, too small to do the work, and in 1863 a Corliss engine, driving four centrifugal pumps, capable of pumping about 2500 gallons per minute, was put up. In 1866, the West engine, still in use, and capable of pumping 5700 gallons per minute, with 16 strokes, was erected, and the same year the shaft was sunk to a depth of 132 feet. The centrifugal pumps have since been removed, as the loss by friction was found to be 47 per cent.

Total Amount of Water to be Pumped.—The following summary may be interesting as showing the total pumping capacity of all the pumps about the mines:

The new engine,	17,000	gallons per minute.
The West engine,	5,700	" " "
The Bull engine,	1,800	" " "
The small engine,	235	" " "
Total,	24,735	" " "

or 35,618,400 gallons per day.

The blende, as it comes from the mines, is crushed in a Blake's crusher, and passed over a sieve with one mesh to the inch. The larger pieces, which pass over the sieve, are separated from the gangue by hand, and the ore sent directly to the work, or roasted in heaps 26½ feet long, 14½ feet wide, and 8 feet high, holding 50 tons. The ore is placed upon iron grates supported by two lateral walls and one central wall, all of stone. The centre wall is three feet thick, being twice the thickness of those on the sides. Wood placed beneath the grates is used for firing. The small stuff which passes through the sieve, when it comes from the crusher, is, at present, laid aside for future treatment. The crusher needs about 10 horsepower, and, with one man to feed it, does the work of four men breaking ore by hand. The silicates and carbonates are washed, sized, and the larger pieces sent at once to the works. The sands are concentrated by buddling or jigging. The conical washer, in which the ore is washed, is

10 feet 2 inches long, 5 feet 2 inches in diameter at the large end, and 3 feet at the smaller end. The ore is fed in at the larger, and worked up to the smaller end by means of teeth 6½ inches wide and high, set slanting. From the washer, the ore passes into a revolving screen attached to it. The meshes of this screen are 3¼ inch. The pieces which are too large to pass through this screen are sorted by hand, and the ore sent at once to the works. The silicious ore deposited by the water is rewashed in the roller before being buddled. Sometimes the earthy ore occurs hard enough, and sufficiently free from sand, to dispense with washing.

The buddles used are of the regular Cornish pattern, the pulp being fed at the centre, and the discharge being on the circumference. The sand pile, when formed in the buddle, is 13 feet 8 inches in diameter, and 2 feet deep on an average, being higher in the centre, and sloping down towards the margin. Each buddle holds about fifteen tons. Sweeps, five feet in length, attached to revolving arms, push the pulp along as it runs over the conical pile already formed, serving to keep the surface in good condition, and facilitating the deposition of the particles according to their specific gravities. When a buddle is finished, the pile is divided into concentric rings. The innermost of these is regarded as ore, and, after a little more treatment, sent to the works; the next is reworked in the same buddle, and the third portion in another buddle. Keeves are also employed. These are 3 feet in diameter at the top, 2 feet at the bottom, and 3 feet deep. After stirring the ore thoroughly with water till the tub is full, it is allowed to settle, the keeve meanwhile being tapped with an iron bar.

A continuous jig is being tried for concentrating the sand. The dressed ore is transported to the smelting works, which are situated in South Bethlehem, about four miles distant, by wagons drawn by four mules each, and carrying 3½ tons.

Metallurgical Processes.—The oxidized ores used for the preparation of zinc-white generally contain about 20 per cent of zinc. Three hundred pounds of ore, mixed with one hundred and fifty pounds of pea or dust coal, are fed together through chilled-iron rollers and then on to a screen for the purpose of sizing. Fine and coarse ores are not treated together, though subjected to the same subsequent process, which consists in a volatilization of the oxide of zinc by heat, a cooling of the gases, and the collection of the zinc-white in long bags of ordinary muslin, the gaseous substances passing through the interstices in the cloth.

The furnaces are of two kinds, single and double. The former are charged only at one end, and only hold a little over a third of the charge of the latter, which are provided with a working door at either end. The single furnaces are 5 feet long and 3 feet wide, covered with an arch of firebrick, which, at the centre, is three feet above the hearth. The opening into the flue is 18 inches square, and the hearth consists of an iron grate made of heavy rolled iron, with perforations to allow the air to pass through. The front opening or charging door is three feet long, and arched so as to be one foot high at the centre. These furnaces cost about $150, and are charged with 240 lbs. of ore, 120 lbs. of coal, and 100 lbs. pea coal as a bed. The double furnaces have an opening 30 inches square into the main flue, and are provided with grates, of similar construction to those used in the small furnaces, 16 feet long by 5 feet wide. The working doors are of the same dimensions as those of the small furnaces. The walls are all of firebrick, 8 inches thick, and last about eight years without repairs. The double furnaces are charged with 640 lbs. of ore, 320 of coal, 240 of pea coal as bedding. No fluxes are added, the object being to keep the charge from becoming impervious to the blast, which is furnished by four fan-blowers.

The process lasts four hours for each charge, and considerable attention, on the part of the workmen, is necessary to keep the cinder porous and avoid the cooling of the fire by an excess of blast. Each workman has four furnaces under his care, and cleans and charges one each hour.

The oxide vapor passes from the furnaces along a conducting channel over a sheet of water, into a cooling tower 75 feet high and 80 feet in circumference at the base. Much of the damp, impure oxide settles in this tower, and the remainder is conveyed down another tower 50 feet high, and by an exhaust fan is forced, through a conducting channel, into the bag-rooms. This conducting channel is floored with sheet zinc, and serves as a cooling-chamber. in which another portion of impure oxide collects. The muslin bags in the bag-room are 30 feet long, and are attached to the sheet-iron tubes that convey the oxide from the cooling-chamber, so that they hang down perpendicularly. They are shaken by the bagman every four hours, and the oxide removed every twelve hours. After some preparatory treatment this oxide is packed and shipped.

The Spelter Works.—Both blende and oxidized ores (silicates and carbonates) are used in this branch of the work. The latter are roasted in large kilns, with one ton of coal to ten of ore. The diameter of these kilns, at the largest part, is about 10 feet. The roasting requires twenty-four hours. The roasted material is crushed with coal, 100 tons of ore to 40 of coal, and when sifted is ready for charging into the retorts.

The blende, after being roasted in heaps at the mines, is first crushed and then roasted as nearly dead as possible, in reverberatory furnaces, after being mixed with 40 per cent of coal dust. From one to two per cent of sulphur is, however, still left in the ore.

The retorts are made at the works of a mixture of fresh fire-clay and ground fragments of old retorts, and are 42 inches long, 9 inches in diameter outside and 6 inside. The condensers fitting by a level in the retorts, are 16 inches long, 6 inches in diameter at the largest and 3 at the smallest end (from outside to outside), the shell being a little over ½ inch in thickness. Fifty-six retorts are placed in each furnace, in seven rows, eight retorts being in a row. Beneath the retorts is placed a row of six-so-called cannons to break the heat. These are 3 feet 4 inches long, and 7 inches in diameter, outside, and are not charged. The retorts rest at the back on ledges, and at the front on plates of firebrick 24 inches long, 9½ inches broad, and 2 inches thick, supported by vertical firebrick pillars 11 inches high. The furnaces are built in groups of four, the internal walls being entirely of firebrick, and the external ones of common brick, lined with firebrick. The walls of each furnace inclose a space 8 feet 3 inches by 2 feet 6 inches, the internal walls being about 18 inches, and the side walls 2 feet 6 inches thick. The slant at which the retorts are placed varies with the purity of the ore, but is generally from 3 to 6 inches from end to end. The furnaces have a framework of cast-iron to add strength, and flat iron plates are placed in front of the retorts to support the condensers, ladles, etc.

Forty pounds of the mixture previously mentioned, is charged every twelve hours into each retort, excepting those in the upper row, which are charged every twenty-four hours, with skimmings, impurities, etc., containing from 60 to 65 per cent of zinc. As soon as oxide of zinc is seen burning at the ends of the condensers, prolongs of sheet-iron, tapering to a fine point, are put on to the condensers, to save the escaping zinc. Every twelve hours the zinc is collected in ladles, and poured into moulds 7 inches by 24, and 1 inch deep, forming ingots which weigh from 40 to 45 lbs. each.

A block of four spelter furnaces costs about $5000, and one double reverberatory furnace for roasting, about $2500.

The process which actually takes place in the retort is the following: The air introduced with the charge causes an imperfect combustion of a portion of the carbon present forming carbonic oxide (CO), which reduces oxide of zinc to a metallic state, by taking oxygen from it, and forms carbonic acid (CO_2). We have then present in the retort, at a high temperature, oxide of zinc, carbon, and carbonic oxide. By the reduction of two atoms of zinc-oxide to a metallic state, one atom of carbonic oxide is converted into carbonic acid, and one atom of carbon into carbonic oxide, and so the process goes on, continually repeating itself till the contents of the retort are exhausted. The following formula may make the action clearer:

$$2ZnO+C+CO=2Zn+CO+CO_2.$$

From carbonate and silicate ores containing 47 per cent of zinc, there can be actually extracted from 34 to 35 per cent, and from roasted blende containing 47 per cent, 33 to 34 per cent. The difference is due to the presence of the small quantity of sulphur previously mentioned.

The spelter works deliver about 65 hundredweight of metal per day to the rolling-mill, where it is remelted in a reverberatory furnace and run out into shallow moulds of various sizes according to the gauge of sheet metal on which the mill is running. After passing through the rolls till reduced to the proper thickness, and having been previously annealed and trimmed, the sheets are packed in casks containing 1200 lbs. each. (Drinker, 1871.)

Distribution of the ore

Zinc ore has been found in paying quantities only in an extremely restricted area in the immediate vicinity of Friedensville and about half a mile northwest from that place. Considerable prospecting has been done over a much larger area throughout the Saucon Valley and elsewhere in the Allentown region, but without success. Reports of zinc from other places have been circulated at many times, but have never been confirmed. Traces of zinc have been found in some limestone drill cores about one mile west of Friedensville, in the limonite iron ores about 1½ miles west of that place, and in the Hellertown cave.

Character and composition of the ore

The zinc ores first worked in the Friedensville region consisted almost entirely of calamine, together with some smithsonite mixed with the residual clay formed by the decomposition of the Beekmantown limestone. With increasing depth of mining the calamine and smithsonite decreased rapidly and zincblende (sphalerite) intimately associated with pyrite and marcasite became more common.

The calamine was found in irregular segregations in the clay, in fissures in the limestone, or in the porous, partially silicified limestone, often in botryoidal or stalactitic forms. Sheets or plates from 2 to 3 feet square and from one-eighth to a quarter of an inch thick are said to have been found in crevices in the limestone. These masses of calamine were coated with small crystals of the same mineral. The crystals of calamine are small but clear and lustrous, and range from colorless to yellowish and greenish-blue.

The smithsonite was usually inconspicuous and occurred as white scales or granular masses coating the calamine or blende, or on the walls of the limestone fissures, or as yellowish-brown porous masses. The larger part of the smithsonite mined was amorphous and occurred in botryoidal, stalactitic, or laminated masses. Occasional plates of small clear crystals with vitreous to pearly luster were found. White, gray, or colorless crystals are most common, but greenish-white to greenish-yellow crystals are found. The yellow crystals probably contain greenockite. Druses of smithsonite coating crystals of aragonite and quartz have been found, showing the later deposition of the smithsonite.

The smithsonite and calamine were formed by oxidation of the sphalerite, but the depths at which the sulphide was encountered in the different mines were not uniform. In the Ueberroth mine, for example, calamine was found to the depth of 200 feet from the surface; a mass weighing 8,200 pounds from that depth was exhibited at the Centennial Exposition. During the prospecting by diamond drill, some calamine was found at a depth of 975 feet. On the other hand, some sulphide ore was found only a few feet from the surface in the Old Hartman and Correll mines. This difference was undoubtedly due to meteoric waters bearing oxygen moving downward, along certain strata with greater freedom, and changing the sphalerite to calamine or smithsonite. The vertical limestone strata of the Ueberroth mine readily permitted the surface waters to pass between the bedding planes to greater depths than in the Correll and Old Hartman mines, where the beds of limestone are less steeply inclined.

The Friedensville sphalerite, or zincblende, is of a peculiar character, essentially unlike any other found in the country. In the main, it occurs as compact gray to bluish-black masses having a prominent conchoidal fracture and rarely showing any traces of crystallization. In one educational institution specimens of the compact ore from this locality were preserved in a quiz set of minerals. Few students ever identified it by eye examination. It is translucent in thin pieces and rings when struck. Much of it resembles dark blue limestone, from which it is readily distinguished, however, by its greater specific gravity. Sphalerite of a light resinous color, and well crystallized, occurred in small veins in the limestone and, less commonly, small honey-yellowish crystals were found on the sides of cavities in the limestone. As sent to the works, the sulphide ore contained from 35 to 40 percent zinc. The noncrystalline structure of much of the ore and the presence of pyrite render its concentration difficult.

In 1935 D. M. Fraser and R. D. Butler presented independent results of their microscopic examination of the Friedensville sphalerite. The following paragraphs are quoted from their articles:

Description by D. M. Fraser

Sphalerite appears in two distinct types. One, the more common blackjack variety, is coarse-grained and massive with the broken surfaces showing cleavage faces with random orientation. The other type is chert- or flint-like in appearance, ranging from gray-brown to black in color, is dense, massive, and breaks with a conchoidal fracture.

In thin-section the coarser-grained variety is dark brown in color and shows a complete network of fractures traversing the mineral. Between crossed nicols it is noted that the mineral has a clouded appearance, not only adjacent to the fracture planes, but also for a distance inward equal to several times the width of the apparent fracture zone. Also when the clearer, less prominently fractured parts of the sphalerite are examined, it is found that their diaphaneity is conditioned by countless smaller breaks which appear to be mainly cleavage planes and by numerous granule or rod-like inclusions having diameters of only a few microns. Some of these may be cadmium, probably in the form of the sulphide, but they have not been proven to be such. X-ray studies in progress at the present time may give more definite information on this point.

Inasmuch as the clearer, more yellowish sphalerite found in the oxidized ore shows numerous cleavage cracks but is lacking in inclusions and in the network of fractures with crushed borders, it is suggested that the black-jack variety found in the primary ore may be less diaphanous and of a darker color due to these features as well as its probable higher iron content.

In plane polarized light this yellow-brown to dark brown sphalerite is seen to be a granular mass wherein the individual grains are more or less indefinable. This is due to the presence of fractures even in what are apparently the more distinct grains, and also to the overlapping of grains.

In a thin-section of the material whose grain size is of the order of several microns in diameter, a few grain-thicknesses are necessary to build up the thin-section which is close to thirty microns thick.

Between crossed nicols two types of material are evident. Brownish material appears in a network of anastamosing wavy bands whereas blacker material lies as elongated areas within the network. The former is interpreted to be the more intensely broken material which is similar in appearance to the crushed areas bordering the fractures in the coarser grained sphalerite. The latter are thought to be "augens" of sphalerite which escaped the minute fracturing of the neighboring material. If this is a correct interpretation, it might be preferable to speak of these specimens of sphalerite as being mylonitized and possessing flaser structure, to indicate the incomplete crushing.

Pyrite is abundantly distributed through the primary ore. The great majority of the pyrite is present as irregular masses or as euhedral to subhedral crystals which were deposited on sphalerite layers in fissures or as replacements of sphalerite. In some places pyrite has been fractured and the fractures filled with sphalerite similar in every respect to the primary vein sphalerite. These relations indicate the deposition of pyrite both prior to and after the formation of some of the sphalerite. (Fraser, 1935.)

Description by R. D. Butler

Microscopic evidences of deformation of the Friedensville deposit are numerous, and formation of the fine-grained cherty sphalerite is thought to have been caused by mylonitization. Evidence of inheritance of texture from the country rock is lacking. There was negligible deformational recrystallization, but aided by solvents, recrystallization of sphalerite has occurred in certain of the deformed facies, and a second generation of pyrite is associated with the recrystallized sphalerite. The paragenesis of the sulphide minerals is: (1) pyrite, (2) sphalerite; and where deformation occurred, (3) pyrite and (4) recrystallized sphalerite may be present. (Butler, 1935.)

Massive pyrite occurs with the sphalerite, and in many places the sulphide ore consists mainly of pyrite. The large quantity of pyrite has been one of the most objectionable features of the sulphide ore. Crystals of pyrite are extremely rare within the ore, but small cubes and pseudomorphs of limonite after pyrite are common in the limestone close to the ore bodies. The ease with which some of the massive iron sulphide decomposes suggests the presence of considerable marcasite, although this has not been definitely determined. Melanterite is common as an efflorescence on the masses of pyrite.

Greenockite (cadmium sulphide), which occurs in many places in association with sphalerite, is found in the Friedensville mines, but only in the amorphous form. It occurs as yellow, greenish-yellow, or orange-colored earthy incrustations on sphalerite, calamine, or limestone. Roepper also found it in clayey material resulting from the decomposition of pyritiferous limestone. A specimen of this material which he analyzed contained 5 percent of cadmium. The greenockite is said to have been separated from the ore at the South Bethlehem furnaces, but this is doubtful.

Goslarite, the hydrous sulphate of zinc, also known as white vitriol, has been obtained in the Friedensville mines in small quantities. It is formed by the oxidation of sphalerite and occurs as incrustations on the sphalerite and as fine acicular white crystals.

Occasional specimens of hydrozincite were encountered while the mines were in operation. The specimens are white mammillary particles or earthy white masses. Halloysite, resembling cloudy amber with a marked conchoidal fracture, occurs rarely. The mineral is very brittle and has a very low specific gravity.

The mines furnished considerable quantities of a clay-like material occasionally known as ''tallow clays,'' but in this region described by Roepper as a new mineral to which he gave the name ''sauconite.'' This is fully described in the chapter on Mineralogy.

At one time the Lehigh Zinc Co. encountered a considerable quantity of the ''sauconite'' in fairly pure form and shipped it to the oxide furnaces. Although the material proved to be satisfactory for the manufacture of zinc oxide, no further shipments were made since it usually was taken from the mine with the other ore and was washed out with the clay.

Masses of white kaolin are common, although most of the clay contains various impurities. Quartz is especially abundant and occurs as a compact quartzite produced by metasomatic replacement of limestone, as thin veins cutting the limestones in all directions, and as small crystals lining cavities in the somewhat porous altered limestones. An interesting variety of fibrous quartz found in the mines has been called ''petrified horsehair.'' Secondary calcite occurs in many places as cavity fillings and as small crystals. The mines yielded many beautiful specimens of aragonite occurring as radiating acicular crystals as much as one inch long in the cavities in the limestone. Most of the aragonite contains some zinc. One specimen analyzed by Roepper yielded nearly 5 percent zinc carbonate: i. e., $CaCO_3$ 94.20, $ZnCO_3$, 4.73, insoluble residue 0.53.

As the limestone in which the ore occurs is highly dolomitic, secondary dolomite would be expected to occur. Cavities in the limestone lined with the characteristic crystals of dolomite are common. Ocherous limonite derived from the original pyrite or marcasite is common and occasional lumps of turgite (?) and impure wad are found. One specimen of ocherous limonite in the Roepper collection in Lehigh University shows beautiful laminated mammillary structure.

Asbestos of the variety called ''mountain leather'' occurs in some of the crevices in the limestones. Allophane, in the white botryoidal and stalacitic masses, is found in limited quantity. The zinc mines have also yielded a small quantity of lanthanite occurring as aggregations of small rectangular crystals of a delicate pink color and a pearly luster. Although the mineral was reported to have been ''thrown out from a few feet below the surface by the miners when sinking an exploring shaft near one of the veins of calamine,'' it is probable that the mineral originally came from the gneiss a short distance to the north. An analysis was made by W. P. Blake:

Analysis of lanthanite.

Water	24.09
Carbonic acid	22.58
Oxide of lanthanum and didymium	54.90
	101.57

Cerium was not detected, but was probably present inasmuch as it is usually noted in analyses of this mineral.

The ores of the Friedensville region are remarkably free from objectionable minerals such as those containing lead, arsenic, and antimony, and for that reason the spelter and oxide made from them always commanded the highest prices. The following editorial in the Engineering and Mining Journal of June 12, 1886, is interesting in this connection:

> "Lehigh zinc, or spelter, made from the ores of the Friedensville mines, near Bethlehem, Pa., has a world-wide reputation as the purest zinc in the world, and as specially adapted for use in cartridge making; in fact, it is the only zinc yet known that will make a cartridge that will never expand and stick in the gun in firing. The Russian and Turkish governments long ago recognized this fact, and during their last war had expert commissions in this country testing the metal made into cartridges for them, and they even brought over ores from other countries to treat here, in order to determine whether the high quality was due to any special treatment here. It was fully demonstrated that Lehigh zinc is better than any other because the ore is purer, containing neither arsenic nor lead, and that, with Lake copper, it formed the best cartridge metal yet made. Other European nations have recognized the same fact by buying here; but the English government, with its accustomed 'deliberateness,' could not accept this fact without expensive experience of its own. Fortunately this experience came in a little, instead of a great, war. In the Sudan campaign, it is said to appear beyond doubt from evidence collected by Lord Charles Beresford, that in one action with the Arabs twenty-five per cent of the rifles were at one time useless by the jamming of the Boxer cartridge, and as this, no doubt, greatly increased the losses of the British, and lacked but little of annihilating the band of heroes who fought their way forward in their vain effort to rescue General Gordon, it has at last attracted the attention of the government, and a contract has been made for a large amount of Bergen Point Company's Lehigh spelter, with which new cartridges are now being made. The price paid is said to be the equivalent of 8¾ cents a pound.
>
> "All the famous mines producing this exceptional ore are now owned by the Bergen Point Zinc Co., which has now made contracts to send 2,000 tons of this ore to Belgium for treatment."

Ore Occurrence

The Friedensville zinc deposits are almost in the middle of the Saucon Valley, which is of irregular shape and about 8 miles long and 2½ miles wide. It is floored by Cambrian and Ordovician limestones and surrounded by hills of pre-Cambrian gneisses that rise from 400 to 600 feet above the comparatively flat valley floor. The valley represents a down-faulted block (called a graben) of limestone that normally should be about 4,000 feet above the gneiss. This profound faulting is evidenced on both sides of the valley by patches of Jacksonburg limestone brought into contact with the gneiss. One of these patches is near Lanark and the other at the northern base of Saucon Hill. In both places the entire Cambrian series of strata and the Beekmantown limestones of Ordovician age have been faulted out. During the deformation that resulted in this great displacement, and in part by both earlier and later disturbances, the strata of the Saucon Valley have been folded and faulted in a complicated manner. In most places there are insufficient outcrops for the determination of the actual structures or the exact boundaries of the different geologic formations. Core drilling by the New Jersey Zinc Co. has furnished data for determining the existence of a syncline near the mountain just west of Colesville and an anticline with the axis just north of Friedensville, but elsewhere the structures are largely conjectural.

In the descriptions of the ore body by Clerc quoted on a previous page, the main ore is said to be of "remarkable regularity of width, pitch and course." This seems to be borne out by the core drilling. The data at hand appear to show the limitation of the ore to a particular geologic horizon and perhaps to a particular geologic structure. It therefore is necessary to describe the stratigraphy and structure in part, although both of these topics are described more fully elsewhere in the discussions of the geology and structure of the entire county.

The limestones of Saucon Valley belong to the Tomstown, Allentown, Beekmantown, and Jacksonburg formations. The Jacksonburg is easily differentiated from the others because of its argillaceous and low-magnesian beds and also rather abundant fossils. The others are not readily separable, as they are almost devoid of fossils and the strata are almost universally high in magnesia. The separation has been made on the basis of minor lithologic features and a very few fossils. A Beekmantown gastropod was found about 1909 in some of the waste rock near the Ueberroth mine and another one (*Lecanospira* sp.) was found in a small quarry a short distance south of the Friedensville church. Also another one *(Ophileta levata)* is reported from one of the diamond drill cores. We may therefore say with assurance that all known occurrences of zinc minerals in the Saucon Valley are in the Beekmantown limestone and apparently in the lower portion of the formation, which seems to be the same as the Stonehenge member of the Chambersburg region.

Throughout the general region the lower part of the Beekmantown is composed of magnesian limestones with local minor, interbedded, somewhat shaly phases. The upper portion of the formation consists largely of low-magnesian limestones. The usual absence of low-magnesian limestones, other than the shaly varieties, in the vicinity of Friedensville, seems to place the ore bodies in the lower part of the formation on purely lithologic grounds. The entire thickness of the Beekmantown is approximately 1,000 to 1,200 feet.

One of the lithologic features of the Beekmantown present in the Friedensville region and rarely noted elsewhere is the limestone conglomerate (or breccia) shown in the accompanying illustration (pl. 28-B). It seems to have a close association with the ore. In places part of it, particularly the dark-colored cementing material or matrix, has been metasomatically replaced by sphalerite.

Drilling operations have revealed beneath the conglomerate the presence of a low-magnesian argillaceous limestone that has been observed only as badly weathered outcropping beds in the south wall of the Ueberroth pit. The drill holes in the Correll property, as reported to the writer, showed no zinc ore below these shaly strata.

The published descriptions and the mine maps in Bulletin M5, show "veins" of ore. This designation is inappropriate in that the ore body is the conglomerate in which are many veins. The outcropping vertical beds of limestone of the Ueberroth mine are said to have been separated by a few feet of zinc ore. This ore was in part the filling of the original narrow openings between the beds, but mainly the replacement of the adjacent limestone. Joints, generally perpendicular to the beds, likewise furnished places for ore deposition. Accordingly blocks of limestone entirely surrounded by ore were occasionally noted. One gathers from the descriptions that the main veins were on bedding planes. Persistent veins were followed downward to a depth of 200 feet in the workings. Names were given to some of the veins.

The thickness of the ore zone was variable. It is reported to have been about 20 feet in some places, 30 to 50 feet in others. Clerc speaks of six parallel crevices (bedding plane openings) having been worked and ''about as many crossings'' (joint plane veins).

The strike and dip of the main ore bodies is fairly regular in each of the mines. The ore bodies pitch along the strike to the southwest at an angle of about 20°. The vein of the Correll mine, which came to the surface in the open cut, was encountered in the New Hartman mine at a depth of 110 feet. The main ore body of the Ueberroth mine seems to pitch westward. Although considerable prospecting has been done east of the Friedensville-Colesville road along the strike of the main Ueberroth veins, no ore has been found. The ore-bearing horizon, rising to the east, has probably been eroded.

The veins parallel to the limestone strata striking of N.80°E. were remarkably persistent. The Stadiger vein in the Ueberroth mine was worked along the strike for about 1,000 feet. On the other hand, the cross veins following the joints with an average strike of N.10°W. were comparatively short. Where the two sets of veins intersected, the ore bodies were largest and richest. Some of these masses of ore were as much as 60 by 20 feet in cross section.

The vertical extent of the ore bodies has not been announced by the company that has carried on the diamond drill prospect work. Ore was found to the greatest depth explored by mine operations, which was about 300 feet at the New Hartman mine. It definitely continues much deeper. The tenor of the ore as revealed by diamond drilling has not been revealed.

The oxidized ores, which have been practically exhausted in both the Old and the New Hartman mines, were found near the surface in deep pockets that were formed by solution in the limestones, and were associated with residual clay. In the Ueberroth mine the oxidized ores persist to the greatest depth reached, probably in relatively diminished quantity, but of unchanged quality. At lower depths, however, they occur, like some of the blende, as the filling of fissures in the limestone. Most of the blende, however, is a metasomatic replacement.

In some of the parallel veins that are only short distances apart, the blende was found almost at the surface, whereas in others the oxidized ores were abundant at a depth of 200 feet. This irregularity was a serious drawback in working the mines because it was inadvisable to mix the two classes of ore.

Origin

The origin of the Friedensville zinc deposits has long been in dispute and there is a justifiable difference of opinion regarding the explanations that have been offered. Drinker supposes "that the zinc was originally disseminated through the dolomite, in the form of carbonate or sulphide." Later the small particles were dissolved by water carrying an excess of carbon dioxide, converted into zinc sulphate by coming into contact with sulphuric acid formed by the decomposition of pyrite, and finally precipitated in their present location as zinc sulphide through the action of animal matter contained in the limestones.

Lesley held somewhat similar ideas and said that "it is probable that they (lead and zinc minerals) were deposited with the limestone in far greater abundance in ancient ages, and were originally brought into the Appalachian sea as soluble salts, together with the lime and magnesia waters of the primeval rivers" and that "the dissolution of the lime rocks has produced concentrated masses of zinc ore." He compared them to the residual limonite deposits which are found in the same rocks but had no explanation for "zinc being substituted in the place of iron."

Clerc suggested a deep-seated origin in his published statement that "they belong to a class of deposits which seem to warrant a belief in their continuance to a considerable depth."

Kemp states that "the veins were evidently filled by circulation from below that brought the zinc ore to its present resting place in the shattered and broken belt."

In any discussion of origin of the Friedensville zinc ores a sharp distinction between the primary concentration and their secondary alteration must be made. Concerning the latter there seems to be fairly general agreement. But for the primary origin there are radically different views. The question is larger than the origin of the Friedensville deposit alone. It embraces the whole group of zinc ores found in limestones and includes the famous lead and zinc deposits of the Mississippi Valley, the Appalachian occurrences in Tennessee and Virginia, as well as scores of other localities. The problem has been discussed in many articles during the last 40 years. Clearly it is beyond the scope of this discussion to examine critically all of the evidences presented in this broad field.

The problem is whether the primary zinc (and lead) ores were formed by ascending heated magmatic waters or by descending, lateral moving, and artesian ascending meteoric waters. In other words, do they owe their origin to waters ascending from some unknown underlying mass of igneous rocks or do the ores represent the concentration by meteoric waters of metallic sulphides that originally existed as disseminations in the Paleozoic limestones?

In previous articles by the author on Friedensville in 1924 and 1925 particularly, the meteoric origin of these ores was advocated. Artesian waters of meteoric origin were thought to be the media for their concentration. His views are expressed in the following quoted paragraphs.

The writer believes that downward-percolating waters containing carbonic acid derived from the atmosphere and organic matter, sulphuric acid derived from the oxidation of pyrite, and possibly some organic acids dissolved the small disseminated particles of zinc and iron carbonates and sulphides and carried them in solution to places where the water found an easy escape upward, as in the shattered and faulted zones near Friedensville. Several hundred and perhaps several thousand feet of limestone and shale overlay the present exposed strata while this work of concentration was most active and consequently the waters were of considerably higher temperature and had greater power of solubility than those of the present time. The abundance of marcasite found with the pyrite indicates, however, that the ore-bearing solutions precipitated their load under moderate temperatures.

The pyrite and sphalerite were deposited in part in the fissures through which the solutions passed and in part by metasomatic replacement of the limestone. At intersections of fissures the mingling of solutions of somewhat different composition caused increased precipitation and resulted in the formation of the great masses of ore already described. Metasomatic replacement of the dolomitic limestones seems to have been much more common than precipitation of ore in existing fissures. The dense black finely crystalline masses of sphalerite preserve the texture of the original limestone. In some places the contact between the ore and the limestone is sharp and regular but in most places it is otherwise, probably owing to the lack of homogeneity of the greater part of the limestone which permitted the solutions to migrate different distances from the trunk channels.

The Friedensville ore deposits represent the segregation of zinc minerals that were obtained from a great thickness of limestones. The limestones in the vicinity of the mines are probably 2500 to 3000 feet thick, and perhaps as great a thickness has been removed by erosion. The probability is that the ore was collected throughout a thickness of limestone aggregating 5000 to 6000 feet. This is approximately twice the thickness of the limestones of the region but owing to the intense folding to which they were subjected, the vertical thickness in the Saucon Valley was probably doubled.

The process of segregation was undoubtedly slow, but it has extended from the end of the Ordovician, when the first great orogenic movements folded and faulted the limestones of the region, up to the present time. The segregation of pyrite by meteoric waters is probably still taking place and disseminated zinc minerals no doubt are likewise being dissolved near the surface, carried to great depths, and deposited from ascending waters. Thus the formation of the deposits represents a time interval of millions of years.

If objection is made to the inadequacy of the meteoric explanation, some calculations may be of value even though they necessarily rest upon several assumptions. Clarke in his Data of Geochemistry cites 13 analyses of Silurian and Carboniferous limestones that contained an average of .00496 percent Zn. Lindgren (Mineral Deposits) cites other similiar occurrences. In the absence of minute analyses of the Saucon Valley limestones we may assume these figures. Doing so, we find that if only a relatively small percentage of the zinc from the limestones of any particular locality should be concentrated in a greatly restricted region there would be enough to account for the ore of the Appalachian zinc-mining districts. Even though liberal allowances are made for loss, it still seems that the meteoric origin need not be cast aside on account of inadequacy.

When Van Hise, Bain, and Siebenthal and others, were studying the central Mississippi Valley deposits, the prevailing belief was that meteoric waters were the sole agents for both the primary and the secondary deposits. At that time the pendulum swung too far toward meteoric-water origin in the study of almost all ore deposits. It is now swinging toward the other extreme. In regard to the zinc ores the trend during the past decade has been decidedly to the magmatic origin of the mineralizing solutions. There have been few, if any, articles, of importance in recent years that invoked meteoric waters to account for the primary origin of the zinc deposits of the limestones. The present trend seems to be supported in large part by the spectroscopic evidence showing the presence in the sphalerite of minute amounts of minerals now generally regarded as evidence of hydrothermal magmatic waters.

A recent article by Stoiber [1] lists cadmium, manganese, germanium, gallium, and tin as present in the Friedensville sphalerite. He places the deposit in the group of low-temperature deposits. Other articles on the "Lead and Zinc Deposits of the Mississippi Valley"[2] all point to the same conclusion.

Those geologists who accept the magmatic origin of the Friedensville and other similar deposits in the Appalachian region infer the nearby presence of intrusive igneous rocks. In the case of the Friedensville the igneous rocks may have been the basic rocks so prominent in the Triassic or some other concealed intrusives that failed to ascend to the present floor of the Saucon Valley. The evidence and arguments are far too voluminous for adequate presentation in this place.

The writer readily recognizes the force of the arguments advanced by those geologists who accept the magmatic-water origin. Nevertheless the wide distribution of lead and zinc minerals in the limestones of Pennsylvania and other states would seem to indicate magmatic waters as having penetrated to almost all portions of the Paleozoic rocks in the Appalachian region if the magmatic origin is correct. In a publication of this Survey (Bull. M 5) the writer describes lead and zinc occurrences in 26 counties of Pennsylvania, mainly in the southeast portion of the State where the strata have been greatly deformed, but some are in the Allegheny Plateau where folding and faulting are of minor importance. In most cases no igneous rocks are known within scores of miles. If all these occurrences are due to the precipitation from magmatic waters we must reconstruct our conception of igneous magmas in the Applachian Province and admit their presence practically everywhere, a point of view somewhat difficult to accept. A possible alternative is the acceptance of both meteoric and magmatic waters; some deposits formed in one manner and some in the other.

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[1] Stoiber, Richard E., Econ. Geol., vol. 35, p. 504.

[2] Geol. Soc. of Amer., Special Paper 24, 1939.

It is hoped that the spectroscopic investigations will be extended to include specimens from many more occurrences.

If the zinc ore was precipitated from ascending magmatic waters, it is somewhat diffcult to explain why it is mainly found above the argillaceous strata of the basal Beekmantown, the most impermeable rocks of the region, and not below as reported to be the case in the explorations of the Correll property.

The writer feels that existing data do not permit any dogmatic or positive statement as to the source of the mineralizing agents of the Friedensville deposits.

The deposits as originally formed consisted almost entirely of pyrite and sphalerite. Calamine, smithsonite, limonite, greenockite and much of the quartz, calcite, and dolomite are all secondary and are the products of alteration by surficial waters. Water charged with silica converted part of the sphalerite into calamine, and carbonic acid changed other portions into smithsonite. In all probability part of the sulphide ore was oxidized to the sulphate and removed in solution, though the richness of the calamine and smithsonite veins seems to indicate that little of the zinc was removed. Part of the pyrite and marcasite was converted into ocherous limonite, but the greater part seems to have been converted into ferrous sulphate and carried away in solution. Some of this sulphate may have been reprecipitated as pyrite or marcasite at lower levels, but evidence of this is lacking.

No indication of the sulphide enrichment of the zinc ore has been reported, and it is doubtful whether the sphalerite ore has been appreciably enriched. If it was not, the sulphide ore should maintain approximately the same tenor to the lowest depths of profitable mining. In few regions is the sulphide enrichment of zinc ores of much consequence and the Friedensville deposits seem to be no exception. Some secondary sphalerite in the form of small honey-yellow crystals that line the walls of small cavities in the limestones can frequently be found, but it is of no economic importance. Crystals of quartz, calcite, and dolomite occur in a similar manner. As to the paragenesis of the minerals, pseudomorphs of smithsonite after dolomite, and quartz crystals that are coated with smithsonite containing cadmium show the later formation of the zinc carbonate.

Near the surface most of the sulphide ore was changed, although some veins that probably were more compact and less permeable were altered to a depth of only a few feet. Great masses of calamine found at the bottom of the Ueberroth mine, about 200 feet deep, show an unusual depth of alteration. There is a strong probability that some of the more permeable veins will yield oxidized ore at considerably greater depths inasmuch as it has been recognized to the extreme depth of 975 feet.

As any vein is followed downward the blende makes its appearance at the side of the vein, whereas the calamine and smithsonite occupy a continually narrowing portion of the center of the vein, thus showing that the downward-percolating waters found an easier passage through the middle of the vein than at the sides. The presence of sulphide and oxidized ores at the same level was a serious inconvenience on account of the necessity for mining the two kinds of ore separately, and it is said that much sulphide ore which might have been removed at small cost was left in the mine. For reasons already mentioned and also because the spelter made from the oxidized ore was superior to that made from the sulphide ore, the failure to remove all the blende was not considered much of a loss.

Mining

As the oxidized ore lay at the surface in a mixture of residual clay and limestone boulders it was natural to begin mining by the open-pit method. At the Ueberroth mine, where the ore was first discovered, about 100,000 tons of ore was removed in this way. On the exhaustion of the large surface pocket the ore was followed downward along the crevices in the limestone, which were filled with loose oxidized ore. On account of the falling of large masses of limestone, open-pit mining was finally abandoned. Shafts were then sunk and the ore hoisted through them. At the Ueberroth and the Old Hartman mines inclined slopes were driven to the deeper ore bodies to the southwest, and from them levels were opened along the vins.

The incompetency of the enclosing limestone strata required much timbering to hold the rock in place, and many shafts and drifts were destroyed by the settling of great masses of rock. At the Ueberroth mine several shafts had to be abandoned for this reason.

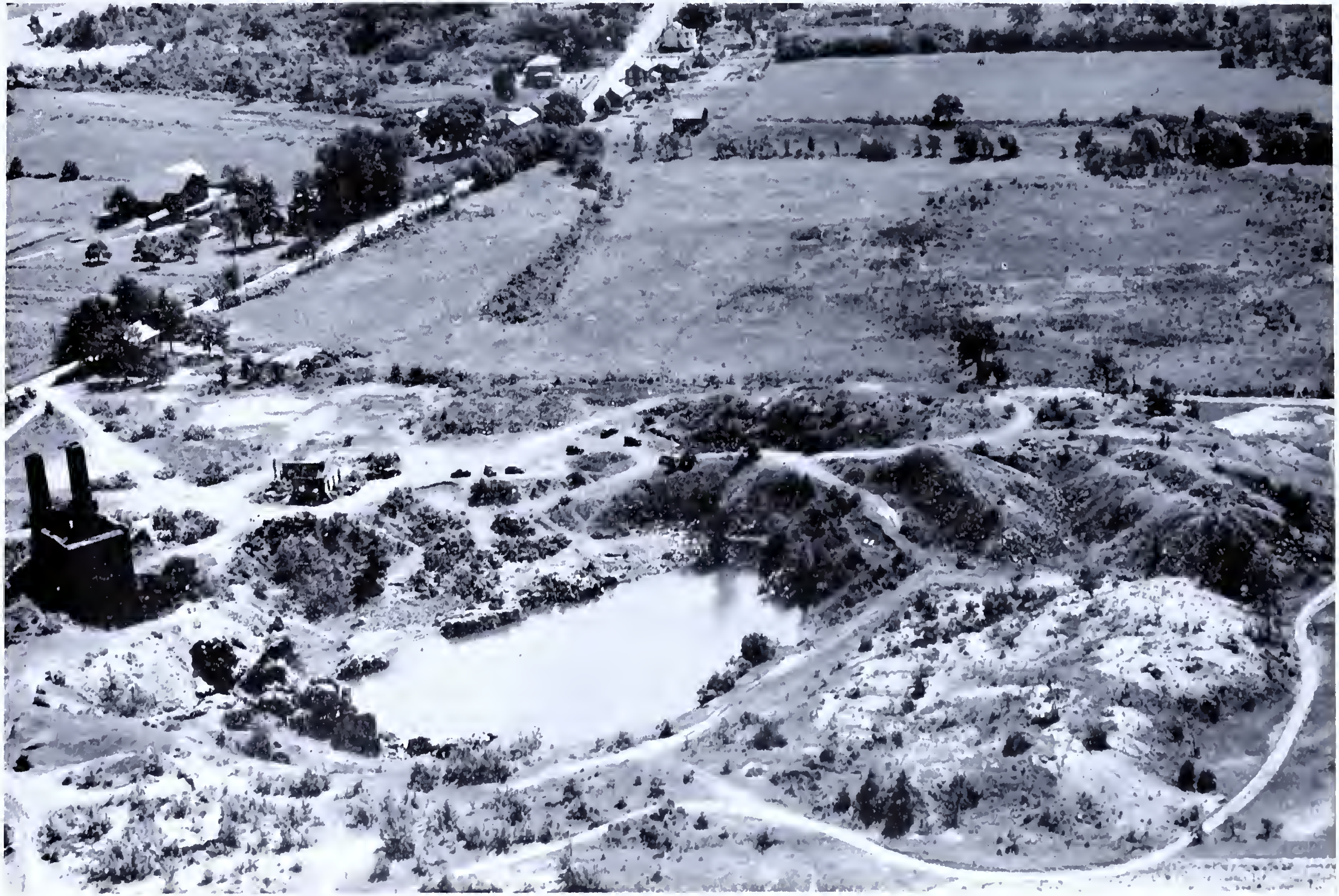
In sinking the shafts and slopes and in driving the drifts it was necessary to remove some of the limestone. Some of this material was hoisted and thrown on the dump, but a considerable portion was put back in the mine to fill old stopes and to underpin loose rock.

Almost at the beginning of mining the water problem became serious. The shattered and cavernous character of the limestones of the Saucon Valley permits easy passage underground so that much water from the upper part of the valley readily found its way into the mines as they were deepened.

At a depth of 46 feet the flow of water was very strong, and at a depth of 150 feet it became necessary to install what was at that time the largest pumping engine in the world. This engine, called ''The President'', was started Jan. 29, 1872, and was run continuously until Oct. 28, 1876, and for a few short periods later. This one engine had a calculated pumping capacity of 12,000 gallons a minute from a depth of 300 feet although it rarely if ever raised that quantity. Most of the time it pumped less than 9,000 gallons a minute. It was never necessary to run all the pumps at their full capacity in order to keep the works free of water. Some published figures that give the amount of water pumped are greatly exaggerated.

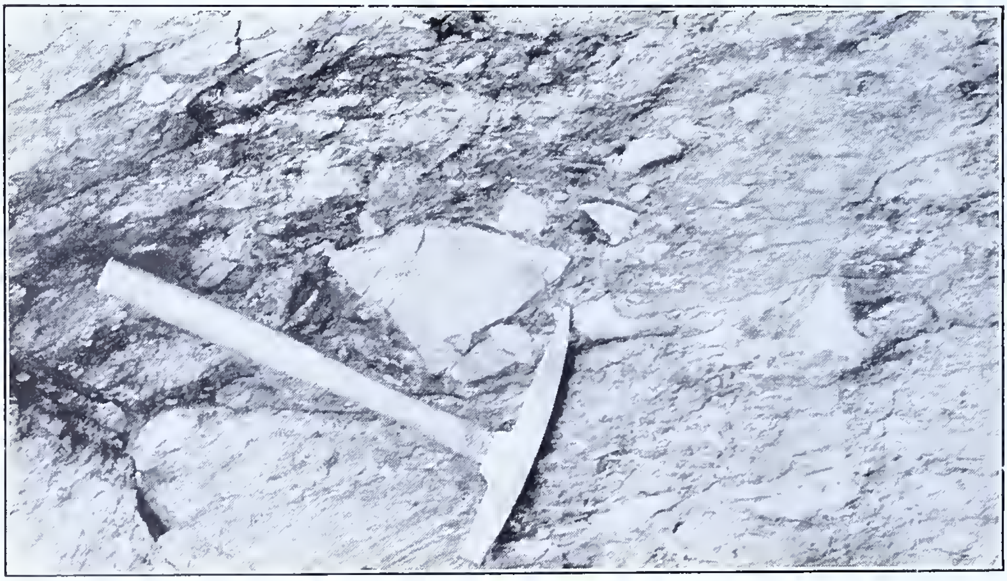
The quantity of water pumped from the mines suggested a remote source for some of the water, but calculations show that after allowing for 40 percent evaporation of the average rainfall of the entire drainage basin of Saucon Creek the amount of water pumped from the mines formed only about one-third of the remaining water falling in the valley. Hence there seems to be no reason to doubt that all the mine waters were of local meteoric origin.

When the big engine was pumping the water from the Ueberroth mine at a depth of 225 feet, the owners of wells and springs in the

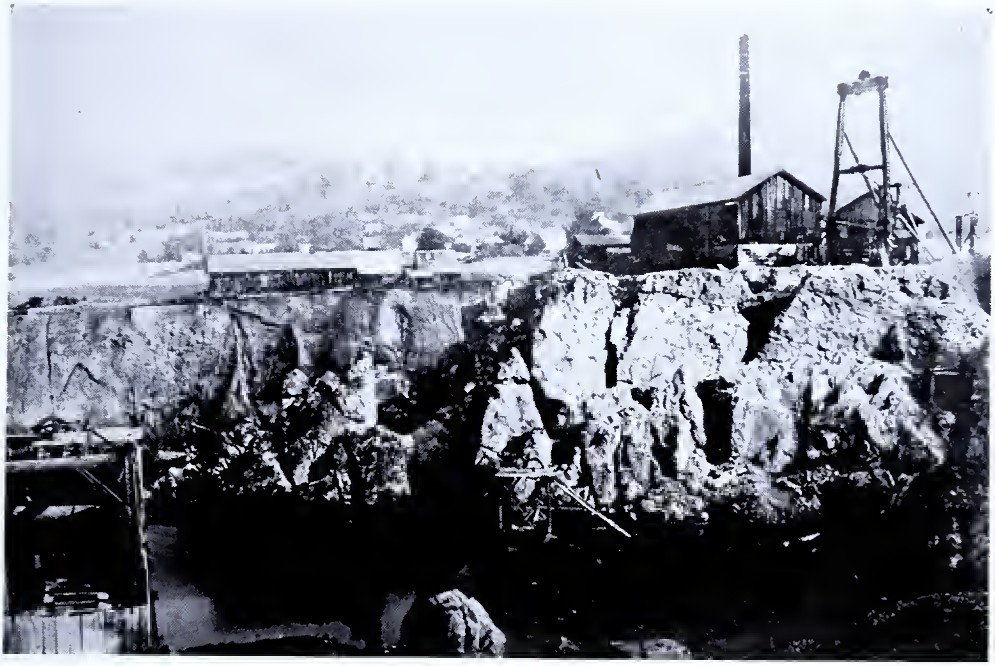


Recent view of Ueberroth zinc mine, Friedensville, Saucon Valley.

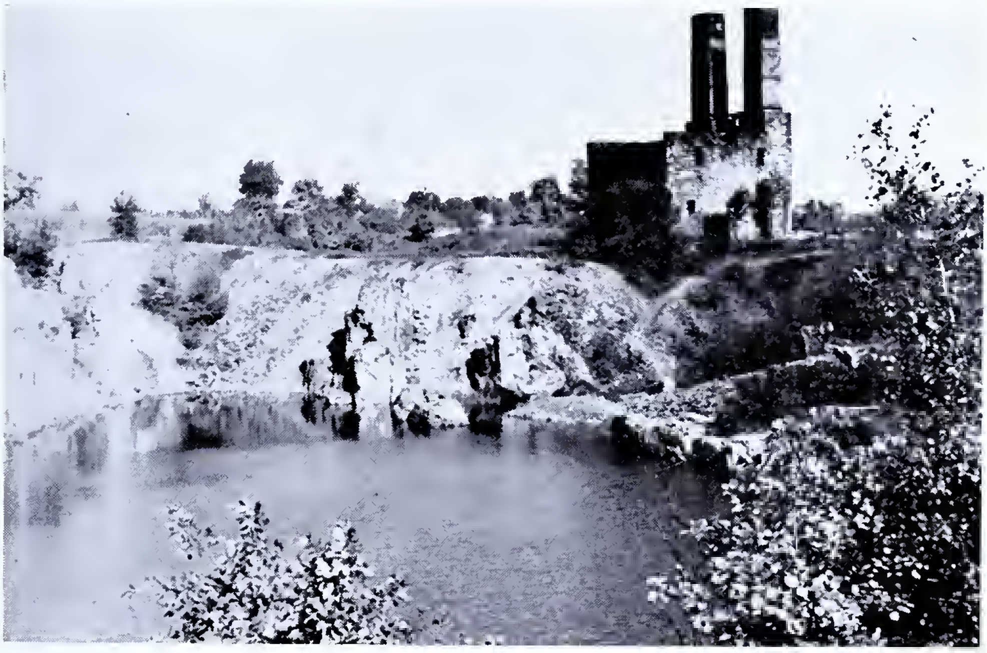
A. Old Hartman mine, Friedensville.



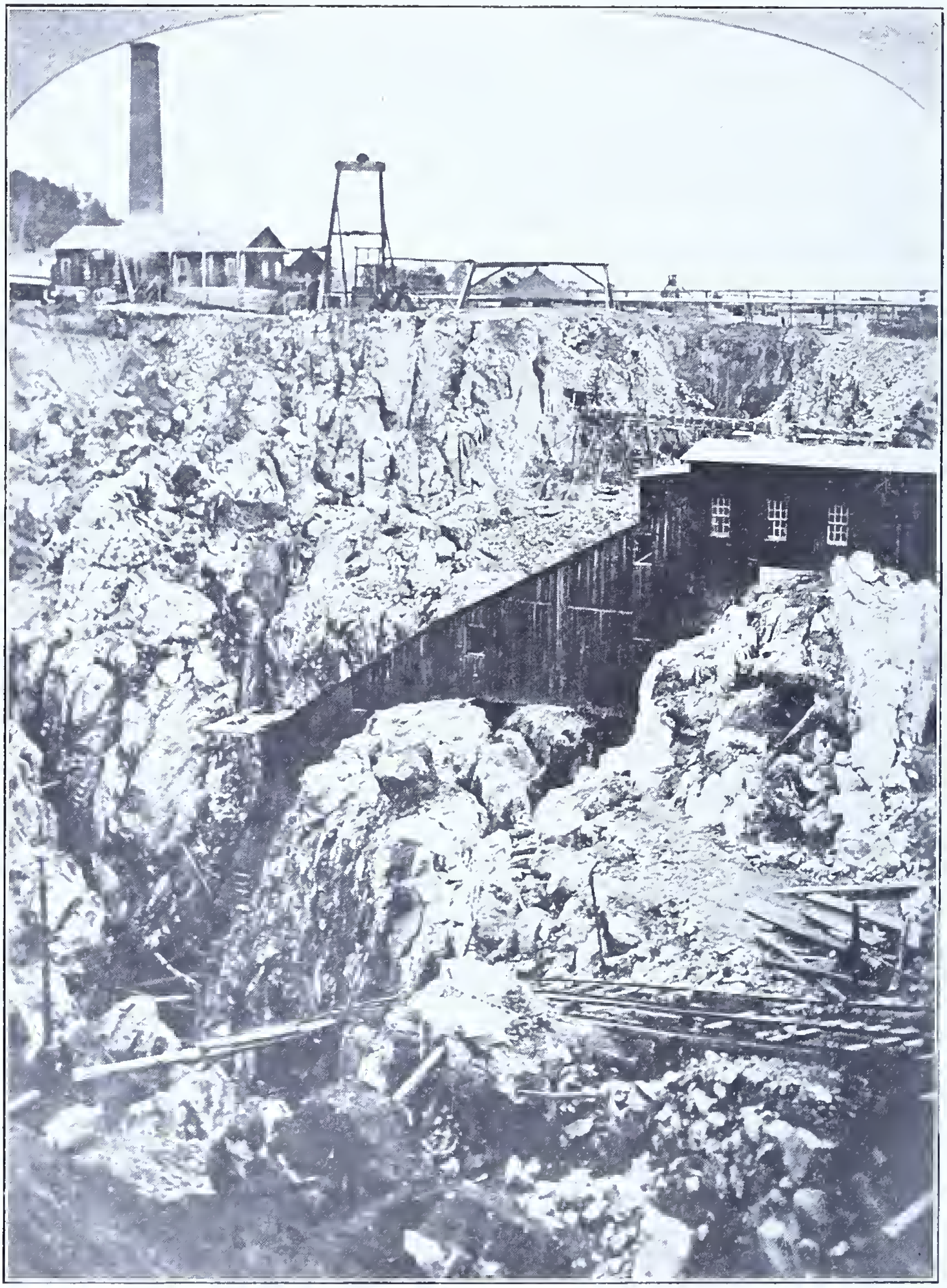
B. Limestone breccia in Old Hartman mine, Friedensville.



A. Ueberroth mine, Friedensville, while in operation about 1877.



B. Recent view of Ueberroth mine.



Ueberroth mine, Friedensville, about 1877, showing mill and open cut.

Saucon Valley attributed the failure of their water supply to this pumping, and law-suits against the company were threatened. Some iron mines in the vicinity ceased operations because of increased water when pumping stopped at the zinc mines. For a time the city of Philadelphia is reported to have considered a plan to run a pipe line from the mines to Philadelphia for an additional source of water supply.

At one time the water of Saucon Creek, at a point about 1¼ miles southwest of the mine, entirely disappeared through an easy passageway into the mine. By means of refuse thrown into the creek bed the opening was sealed. When the large engine was stopped in 1876 the creek below the mine shrank to a small part of its former volume, and it regained its normal size only after the mine had filled with water. In 1868 the pumping cost was said to be $6 per ton of ore, and in 1876, when the Ueberroth mine was closed, the pumping cost was said to be $4 per ton of ore, the greatest item in the entire mining costs. The high cost was due to the fact that only one shift was worked and altogether the daily output was only 55 to 60 tons of ore. For the same cost of pumping a much greater output could have been made.

On account of the different treatment required for the oxidized ores (calamine and smithsonite) and the sulphide ores (sphalerite associated with pyrite), and the difficulty of separating them if they should become mixed, the mining of the different kinds of ore was carried on separately so far as possible. In some places sulphide ore was left in the mines, even though it could have been easily removed. An additional reason for not removing all the sulphide ore was the fact that this ore had to be roasted to remove a large part of the sulphur before it was sent to the furnaces, and the companies were in danger of being enjoined by the courts if the sulphur fumes at Friedensville or South Bethlehem should become obnoxious. It is possible that if the mines are reopened the sulphur gases may be economically utilized in the manufacture of sulphuric acid. The greatest drawback to the profitable production of sulphuric acid will undoubtedly be the large amount of limestone necessarily mined with the ore. The sulphide ore from the Correll mine was made into sulphuric acid at Bergen Point, N. J. For a time the project was profitable, but the increasing amount of limestone in the ore finally caused the company to abandon the attempt to utilize the sulphur.

Milling

Both the oxidized and the sulphide ores as they came from the mine were mixed with impurities and had to be concentrated before delivery to the furnaces. The impurities with calamine and smithsonite were mainly clay and small pieces of limestone, and a few fragments of pyrite and sphalerite, whereas in the sphalerite ore the chief gangue material was limestone. For these reasons the two kinds of ore required different treatment.

As the oxidized ores were brought from the mine, the larger masses were broken by sledges and the richer fragments that happened to be fairly free from impurities were picked out by hand and sent directly to the spelter works. The small fragments mixed with clay were passed through log washers or cone washers. From the washers the ore was discharged on grizzlies or revolving screens and then thrown on picking tables where boys removed pieces of limestone, pyrite, and sphalerite. Most of the concentrate obtained from the washers went to the oxide furnaces.

The water from the washers, which carried the clay and small bits of ore and rock, was drained into settling ponds. Later much of the coarser materials that had been deposited near the inlet of these pits was dug and worked in buddles or tossing tubs and considerable fine calamine and smithsonite were thus recovered. A four-compartment Hartz jig with an eccentric stroke was tried on these sands but was not successful. Sometimes the tailings were found to contain more zinc than the heads. The failure was due to many thin flat pieces of calamine that had a tendency to go with the tailings. The concentrate recovered from the sands was sent to oxide works. The dried oxidized concentrate as sent to the furnace contained about 20 percent zinc.

The intimate mixture of the sphalerite ore and the limestone rendered concentration difficult. In blocks of ore that showed complete gradation from pure sphalerite into pure limestone a clean product could be obtained only after extremely fine grinding. The result was that during the period of most active operations the richer ore was picked by hand and sent to the roasting furnaces or roasting heaps and the remainder thrown aside.

After 1876 sizing and jigging of the sulphide ores was tried. Hand jigs were first used and, later, Hartz jigs having several compartments. They were not entirely satisfactory as the tailings were always high in zinc.

The best of the sulphide ore was roasted in reverberatory furnaces for spelter. Often the lower grade ore was heap-roasted and sent to the oxide furnaces or re-roasted in the reverberatory furnaces and sent to the spelter works.

The best of the hand-picked sphalerite ore contained from 42 to 44 percent zinc; the remainder contained from 15 to 25 percent zinc.

Future

Extensive prospect drilling done by the New Jersey Zinc Co. has doubtless yielded information sufficient to warrant a decision on future plans. The data and conclusions are confidential.

A common belief that the Friedensville mines were closed on account of the exhaustion of the ore is incorrect, because the ore bodies were as large in the lowest workings as near the surface. The veins gave no evidence of dying out as the depth increased and the sulphide ores showed little change in tenor.

Another reason frequently heard for closing the mines was the threatened litigation by the farmers whose wells were drained by the pumping that was required to keep the mines free of water. This explanation is likewise without foundation, as the courts have repeatedly upheld the principle that no mining company is liable for damages incurred by the withdrawal of water from previous users so long as this is necessary in order to remove the ore and the water

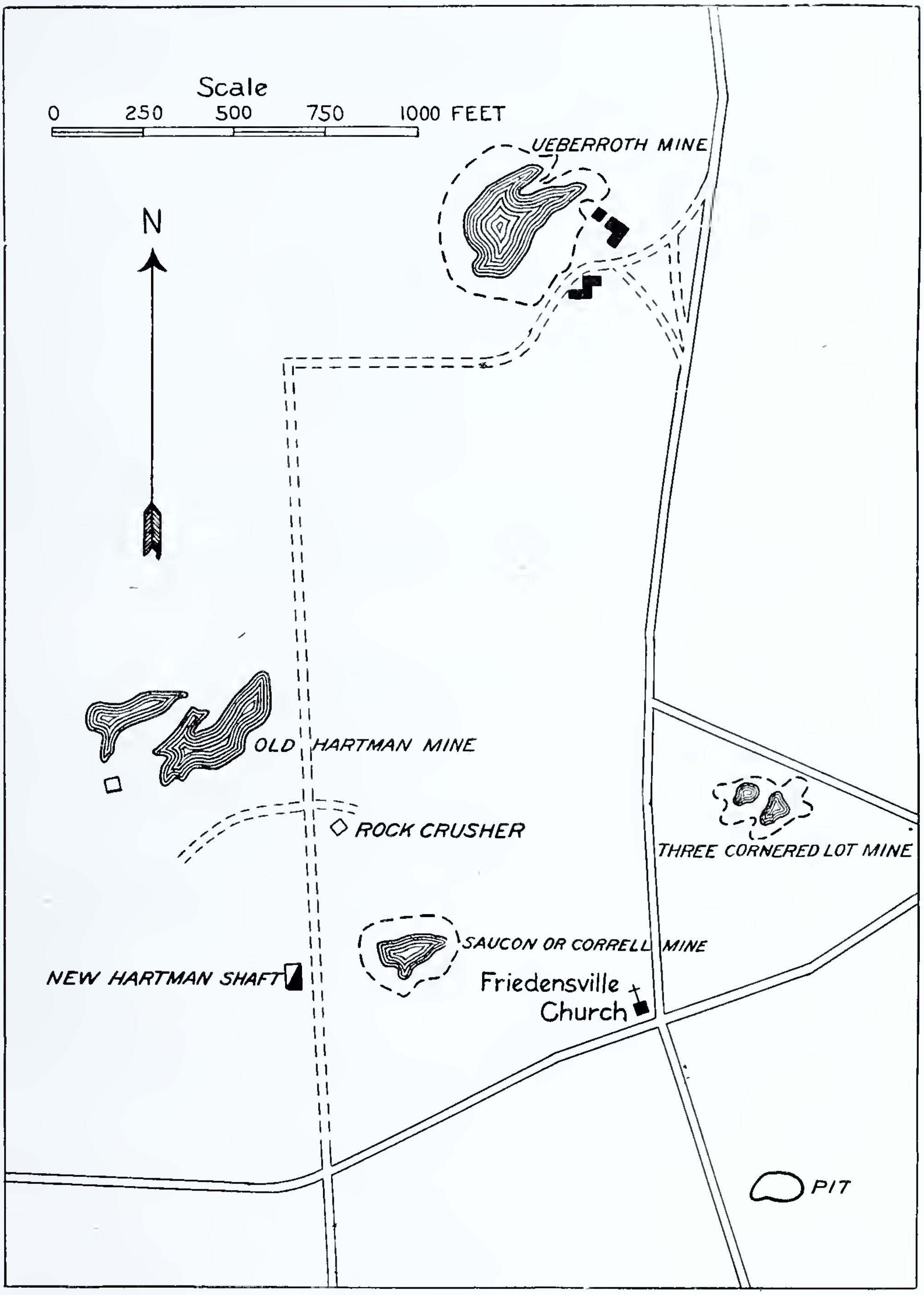


Figure 13. Map of Friedensville zinc mines.

Note.—Figures 13 and 14 were copied from a map of the property of the Friedensville Zinc Co. made by Jacobs & Davies, New York, May 1899, and furnished to the writer by the New Jersey Zinc Co.

is neither sold nor disposed of in such a manner as to damage other property.

The chief reason why the Lehigh Zinc Co. closed its mines, which consisted of the Ueberroth, Old Hartman, New Hartman, and Three Cornered Lot mines, in 1876, was its inability to compete with the New Jersey Zinc Co. in the manufacture of zinc oxide made from the zinc ores of Sterling Hill and Franklin Furnace, N. J. or with the companies operating in the Central States in the production of spelter. The Lehigh Zinc Co. owned the Wetherill patents for the manufacture of zinc oxide and had previously prevented the New Jersey Zinc Co. from producing zinc oxide from the New Jersey ores by bringing suit for infringement of patent. Wetherill patents having expired in 1876, the New Jersey Zinc Co. was about to enter the field with new oxide furnaces. As it was costing the Lehigh Zinc Co. from $4 to $6 for each ton of ore raised merely to pump the water from the mines, while the ore at Sterling Hill, according to the Engineering and Mining Journal of Sept. 30, 1876, could be loaded on the cars at a cost not exceeding 75 cents per ton, it was forseen that competition would be ruinous to the Lehigh Zinc Co. An agreement was therefore made by which the Lehigh Zinc Co. closed its mines and contracted with the New Jersey Zinc Co. for 1,000 tons of ore a month from the New Jersey mines for a period of five years.

Description of Mines

Ueberroth mine. The Ueberroth mine was the largest of all the Friedensville mines (pls. 29, 30). It was worked continuously from 1853 to 1876 and for short periods in 1886 and 1891 and produced about 300,000 tons of calamine and smithsonite ore. Oxidized ores were found to a depth of 150 feet between loose blocks of limestone, some of enormous size. In no other mine in the region did the oxidized ore continue to such depths. At that depth, however, the limestone became solid and the ore veins, which were 12 to 40 feet in width, had well-defined walls. The limestone strata and the main ore beds which lie between them are practically vertical in the Ueberroth mine and strike about N.80°E.

Two very important veins in this mine, known as the Stadiger and Trotter, were worked continuously for a distance along the strike of about 1,000 feet. Another productive ore body was known as the Blende vein. This vein was not worked so extensively on account of the larger amount of sulphide ore which it contained. At the deepest level this vein was well-developed and yielded ore containing about 30 percent zinc. One-third of the ore was rich enough to be sent directly to the smelters; the remaining two-thirds, however, required concentration.

Several shafts were sunk at this mine but these have been destroyed by caving. At present the old open pit, which is approximately circular and measures about 480 feet in diameter, is filled with water to within about 30 feet of the surface. Nearly all the buildings which were formerly near the mine have been completely razed; the pump house and office, the only ones remaining, are in ruins. (See Pl. 27.)

Old Hartman mine. About a quarter of a mile southwest of the Ueberroth mine is the Old Hartman mine, now consisting of two open pits about 400 by 250 feet in extent, both nearly filled with water. As in the case of the Ueberroth, the Old Hartman mine was first worked exclusively for calamine and smithsonite but large bodies of blende were encountered nearer the surface than in the Ueberroth mine. The oxidized ores were worked to the depth of 150 feet although much sulphide ore was found nearer the surface. The last work done in this mine was the driving of a slope to work a fine vein of sphalerite ore.

The limestones of the Old Hartman mine show much brecciation but are less cavernous than in the Ueberroth mine. The water problem here was less serious and the mine was operated for a year after the large engine at the Ueberroth pit was stopped. Had grouting been employed, the necessary pumping might have been considerably reduced. At the present time the water level in the two openings is somewhat lower than in the Ueberroth pit, which seems to show an independent source.

The Old Hartman mine was worked both by open cut and by shafts sunk in the limestones. The vein system is similiar to that of the Ueberroth mine although no veins were followed so far. The veins of the two mines seem to be entirely distinct.

Correll mine. The Correll or Saucon mine is about one-eighth mile southeast of the Old Hartman mine. It was actively worked as early as 1859 and much of the time between that date and 1881, but since that time it has furnished little ore. The mine produced less oxidized ore in proportion to the sulphide ore than did the Ueberroth mine. The ore was removed from an open cut until 1876 after which underground mining predominated and extended to a depth of 200 feet. The limestone strata and the principal ore veins which lie between them, dip S.30°-40°. The limestones are regular and show few effects of disturbance or of solution.

In 1876 a 12-foot vein of sulphide ore was being worked. There is no evidence that the thickness of the vein became greater with depth, but the plan width of the mineable ore increased to 40 or 50 feet down the pitch of the ore shoot toward the New Hartman mine. The whole length of working in the Correll mine was about 700 feet along the strike. The veins were worked to the western limits of the property of the Correll estate and are continued in the New Hartman mine.

The open pit of the Correll mine, now partly filled with water, measures approximately 200 by 300 feet.

New Hartman mine. The New Hartman mine, which adjoins the Correll property on the west, is the only mine in the region that was worked exclusively by underground methods. The ore was found in a vertical shaft at a depth of 110 feet and was worked downward to a depth of 200 feet. Very little oxidized ore was found. The principal ore vein was said to be 50 feet wide when work ceased. Its strike was almost due east, and the dip was 35°S.

Three-Cornered Lot mine. A mine east of the Friedensville-Colesville road and about 700 feet northeast of the Friedensville church is known as the Three-Cornered Lot mine. The open cut, which is partly filled with water, is irregular in shape and has an average diameter of about 250 feet. Here, as in most of the mines, open-cut mining finally gave place to underground mining, and several veins were followed under the road and beneath the property that lies west of the road north of the church. The veins undoubtedly belong to the same system as those of the Correll and New Hartman mines and have the same general strike and dip. The exposed limestone strata dip 35°S. and strike N.85°E.

Other occurrences of zinc ore in Lehigh County

In 1857 the following note was published in the Mining Magazine (vol. IX, p. 182).

> Discovery of Zinc near Allentown
>
> This thriving town, in the Lehigh Valley, was recently the scene of considerable excitement caused by the discovery of zinc beds in the bottom land that skirts the Lehigh River in front of the town.
>
> It appears that some days ago, in digging a well midway between the ironworks and the river bridge, and about half a mile from each of these two points, the laborers employed came to a substance resembling the zinc ore found in the Saucon Valley, whence the Bethlehem Zinc Works are supplied; and on examination it was ascertained that a large deposit of zinc ore had been discovered, whereupon the news spread and the curious hurried to the spot. Of course land thereabout instantly acquired in price the upward tendency of the flood tide.

No further mention of this occurrence has been found, indicating that the material was not zinc ore or that the quantity was small.

Prime (Report DD, p. 5) says:

> Nearly a mile north of Shimersville zinc ore is stated to occur on Nathan Kunkel's farm; it was searched for closely, but no evidence of it could be found on the surface in the way of pieces or bowlders of ore.

It is of interest to note that in 1933 the writer found a small piece of honey-colored sphalerite in a lens of grayish-white chalcedony in a dolomitic limestone quarry a short distance southwest of the junction of the Little Lehigh and Jordan creeks. In view of the wide distribution of sphalerite and galena in the limestones of Pennsylvania it is probable that other occurrences will be reported from time to time.

MANGANESE

Manganese minerals are widespread throughout Lehigh County. Dendritic pyrolusite coatings, resembling fern inpressions, are common on joint and bedding planes in all the different kinds of rocks in the region.

The original source of the manganese is in the crystalline rocks where it exists as one of the constituents in several of the complex silicate minerals. The gneisses and schists of the pre-Cambrian rocks, such as those in South Mountain, probably contained the manganese originally. The weathering of such rocks frees much of the manganese which is carried off by both surface and subterranean waters. By precipitation in the ocean waters it entered into the composition of the sedimentary rocks so that it is now found in the sandstones, shales, and limestones. Here it may be so evenly disseminated through the rocks that it is not evident or it may be concentrated to such an extent as to be recognizable or even to form ore deposits of commercial importance.

The original minerals that carry manganese usually contain more iron than manganese. Under the influence of atmospheric alteration both are converted to hydrous oxides that are dissolved and precipitated under practically the same conditions. The result is that the hydrous oxides of iron and manganese usually occur in close association. In this region probably all of the limonite ores previously described contain manganese normally ranging from 0.1 to 3 percent. This is generally in the form of pyrolusite or wad but may be psilomelane. The manganese darkens the ore; the more manganese, the darker the limonite. The conditions requisite for the precipitation of pyrolusite and limonite are not identical, consequently the two may be and in some cases are segregated. Instances have been cited where the limonite miners picked out and discarded the pieces of black pyrolusite under the assumption that they were detrimental impurities. However, in other cases those limonite ores with larger percentages of manganese commanded higher prices.

If the manganese was present in the soft or pulverulent form, known as wad, it was carried away with the clay in the washing process and lost.

Where the manganese was precipitated with little or no limonite it occurred in pockets, bands, or lenses of varying dimensions. Some of these deposits were of sufficient size to justify separation.

Manganese was particularly noted in several of the limonite mines of Lehigh County described on previous pages. These are mines 5, 6, 7, 94, 138, and 182. The superior quality of pig iron produced by some blast furnaces was believed to be due to the presence of manganese in appreciable quantity. It seems to explain why the Ironton ore was preferred by some. The Ironton mines contained more manganese than any of the other limonite mines. Several hundred tons of manganese oxide are reported to have been shipped from them.

When Dr. Hartzell was operating a mine in the Ironton region about 1906 a lens of manganese ore about 4 feet thick was encountered. It was followed for some distance with the hope that it might develop into a larger body but this did not materialize. The following two analyses have been published by Prime (Report DD, p. 42).

Analyses of Ironton manganese ore

(1 by A. S. McCreath, 2 by Henry Pemberton, Jr.)

	1	2
Silica	4.845	....
Manganese binoxide (dioxide)	77.960	84.88
Manganous oxide	4.320	3.77
Ferric oxide	3.660	....
Alumina	0.711	....
Oxide of cobalt	0.390	1.68
Oxide of nickel	trace	trace
Cupric oxide	trace	....
Baryta	0.152	trace
Lime	0.770	1.90
Magnesia	0.236	0.79
Soda	0.368	0.19
Potash	3.042	3.50
Sulphuric acid	trace	....
Phosphoric acid	0.149	trace
Water	3.980	4.38
	100.583	101.09
Iron	2.562	....
Manganese	52.631	56.58
Sulphur	trace	....
Phosphorus	.063	trace

Prime gives several other analyses of manganese-rich limonite ores from Lehigh County as follows:

Analyses of manganiferous limonites

	1	2	3
Iron	44.500	47.000	26.400
Manganese	9.280	7.464	17.648
Sulphur	0.019	0.003	0.010
Phosphorus	0.316	0.630	0.095
Insoluble residue	6.280	4.940	21.860

1. Iron mine about one mile south of Alburtis.
2. Iron mine about one mile south of Fogelsville.
3. Ironton ore from wharf of railroad.

In Mathews and Hungerford's "History of the Counties of Lehigh and Carbon," published in 1884, is the following note.

> It has been reported that a rich vein of manganese has been found on the premises of Reuben Shubert, near Zionsville, in Upper Milford; and also on the premises of Rev. Eli Keller, at the same place. It is estimated to be worth five dollars per ton. (p. 346.)

Evidently this is the locality where about 1891 a man named Kreiss (?) sank a shaft 90 feet in depth on the farm of the Shubert Estate now belonging to F. E. Graber about midway between Old Zionsville and Powder Valley. Some ore was hauled to Zionsville and shipped to a Thomas Iron Co. furnace. An excess of water interfered with mining.

All the existing information indicates that there is little prospect of ever finding a commercial deposit of manganese ore in Lehigh County. Nevertheless it should be borne in mind that in many respects the same types of rocks and iron ores occur here that in Virginia and other localities in the Appalachian province have yielded commercial manganese ore.

LEAD

As mentioned in the chapter on Mineralogy, lead minerals have not been noted in Lehigh County although galena in small grains might be expected to occur sporadically in the quartz veins of the Tuscarora sandstones and conglomerates.

Notwithstanding the improbability of ever finding other than traces of lead minerals in Lehigh County the Engineering the Mining Journal of Aug. 2, 1884 contained the following item copied from the Eastern Express.

> William Schwenck of Mount Carmel and Jeremiah Savidge of Sunbury, have organized a company with a capital of $25,000 to mine "lead ore" on a tract of land six miles from Allentown. The ore will be shipped from Allentown to Sunbury for smelting. The mining, freightage, etc., will cost $20 a ton. The ore assays $85 per ton.

The exact locality is not known. No further reference to this item has been found.

COPPER

No copper ore has been discovered in Lehigh County. A few copper minerals have been found as described in the chapter on Mineralogy. Some prospecting for copper was done near Powder Valley many years ago but no record of results has been obtained.

GOLD

Gold is discussed in this report merely to call attention to its absence in this region in profitable quantities and to warn credulous persons to avoid the expenditure of time and money in searching for it. Reports are current that gold has been found in many places in the southern half of the county, and considerable money has been spent in sinking shafts, mostly in the gneiss. It seems that in some places small particles of pyrite or chalcopyrite in the rocks have been mistaken for gold, and that in other places operators of the divining rod have been the means of exciting false hopes of hidden wealth. Some unscrupulous or incompetent assayers have reported high gold assays in rocks that were shown later to be absolutely barren.

Two shafts, 150 and 180 feet in depth, were sunk in the Triassic conglomerate about 1½ miles east of Limeport in search of gold. It was reported that a vein of free-milling gold ore was found which contained about $30 in gold and $15 in silver to the ton but that the vein was soon exhausted. These statements seem to be extremely questionable and can not be verified. The deposit was later worked for a time under lease by four men, who installed a sluicing system, but the project was a failure. When visited some time after operation had ceased the only metallic substances observed in the rock on the dump were a few small particles of pyrite and chalcopyrite in the cementing material of the conglomerate.

About 1903 a shaft 103 feet in depth was sunk in gneiss about 1 mile southeast of Mountainville. The materials about the opening include pegmatite carrying much coarse hornblende and some quartz, magnetite, pyrite, and feldspar. It was claimed that some valuable rare minerals were obtained, but careful examination has failed to detect their presence.

About 1840, according to report, an organization was formed to mine gold at Powder Valley. A shaft was sunk midway between the old mill and the mill pond. ''Nuggets'' of gold were said to have been found. The promoter disappeared when the venture failed. The topographic sheet of the region published in 1883 shows ''Shaft'' north of the place pointed out by old residents as the site.

Gold is also said to have been found in the Backenstoe graphite mine, 1 mile east of Vera Cruz station. This mine is described under Graphite.

Items such as the following appear in the local press from time to time but nothing further results. This was published under date of May 22, 1923. Most are as unlikely as this one where the country rocks of the region mentioned are Martinsburg slate and Beekmantown limestone.

> "People living in the vicinity of the farm of Thomas P. Roth, at Kernsville, North Whitehall township, say that traces of gold have been discovered on the Roth farm through efforts to locate an old mica mine. Soil and stones have been assayed and it is reported that placer gold was present. Mineral rights have been turned over to the Ontario Mines Co. C. T. Hickey is in New York looking up the necessary machinery to begin operation. The gold is believed to extend over a large area, including the Trexler and Hardener farms and the territory up and down the Jordan creek."

Though very accurate assays of some of the pyrite so common in the rocks of the region may show traces of gold, it is extremely improbable that gold in paying quantities occurs in the rocks of the county.

PYRITE

In the discussion of the origin of the limonite on previous pages attention was called to the large amount of pyrite found in the lower workings of these ores, and an explanation of its origin was given. Pyrite has probably not been more generally noted in the mines because the quantity of water struck in the lower levels caused the mines to be abandoned before the pyrite was reached. H. M. Chance* and Charles Catlett** have ably described the occurrence of pyrite in association with limonite in the Appalachian region and have discussed the problem of its origin.

It seems probable that the limonite of the Cambrian (Hardyston) sandstone and part of the limestone regions of the county has been formed by the oxidation of pyrite that was precipitated from solution in ascending artesian waters. If this theory of the origin of the limonite ores is correct deposits of pyrite must be widespread in the region.

Crystals or rounded concretions of pyrite are common in all the rocks of the region, but in only a few places have deposits of possible commercial value been found. Though some pyrite has been marketed it has all been obtained from mines that were worked primarily for iron ore. The deposits are so unlike that they must be described separately.

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* A new theory of the genesis of brown hematite ores: and a new source of sulphur supply: Am. Inst. Min. Eng., Trans., vol. 39, pp. 522-539, 1909.

** Idem, pp. 916-920.

The largest known deposit of pyrite in the county is about 2 miles northeast of Emmaus, on the northwest slope of South Mountain. It occurs in the deepest working of one of the numerous limonite mines that form an almost continuous line for about 3 miles along this slope of the mountain. The pyrite has been deposited by replacement of the quartzite, and specimens can be obtained that range from practically pure pyrite through pyritic quartzitic sandstone to quartzite in which no pyrite can be detected. The pyrite is granular, and, as determined by Chance, the grains ''are generally small enough to pass through a 20 or 30 mesh screen; a large portion passes through an 80-mesh screen, and a considerable percentage is of still finer texture.'' No data are available regarding the exact occurrrence of the pyrite ore, but it probably forms layers or lenses of variable thickness interbedded with non-pyritiferous sandstone.

During the First World War extensive core drilling was done in the vicinity of this mine, and some shafts were also sunk. Although detailed reports are not available, it is said that considerable pyrite was found, but the project was abandoned because of the expense of pumping the enormous quantity of water that was encountered and also because of the difficulty of keeping the shaft open on account of the clay and loose rock in the upper part, which tended to move slowly downhill.

The depth at which the deposits of pyrite occur depends almost altogether upon the configuration of the region. Where the water level is high and erosion is relatively rapid much pyrite may be expected at a depth of 100 feet or perhaps less. In most places, however, pyrite in workable quantities would not be reached at less than 150 to 200 feet below the surface.

In regard to the pyrite that underlies the deposits of ''mountain'' limonite ore the available information seems to indicate that the supply is abundant but at present of doubtful value.

In the limestone regions pyrite has been found in large quantities in the Friedensville zinc mines (which see). When the mines were worked the sulphide ores were less favored than the oxidized ores and in some of the mines the sulphides were left. These ores consist mainly of pyrite but contain more or less sphalerite. It seems probable that some of these ores which are too low in zinc to be considered zinc ores may be of value on account of the pyrite.

In the limonite iron mine three-quarters of a mile east of Lanark considerable pyrite was found in the lower levels, and had work continued no doubt much more would have been revealed. The mine was compelled to close when pumping ceased at the zinc mines, as the amount of pumping required for the drainage of the iron mine was too great for successful operation. Next to the Friedensville zinc mines this locality is regarded as the most promising place for pyrite ore in the limestone areas of the county.

Some of the limonite mines contained so much pyrite that at times it was separated from the limonite ore and shipped. In general it was disseminated through the clays in minute quantities too small for separation. Numerous occurrences are mentioned in the descriptions of the individual mines on preceding pages. Some of the mine dumps contain black pyritiferous clays that give off distinct sulphurous odors.

The Ironton mines had considerable pyrite in the black clays, but the only place known to the writer in the iron mines of the limestones where pyrite was actually mined and shipped was in mine 182 at Breinigsville. This occurrence was described by H. D. Rogers in his Second Annual Report (1838, pp. 26-27) as follows:

"About a mile and a half west of Trexlerstown, in Lehigh county, in a tract where the surface of the limestone formation is quite level, there is a very large deposit of iron ore, some of which, without altering its external structure, which is that of the cellular and pipe ores, has passed to the condition of sulphuret of iron, or the common copperas mineral. This mine was originally worked for the iron ore which it contains, this being still an object of pursuit; but the person conducting it, finding the good ore to be mixed with a large quantity of the sulphuret of iron, referred to me about three years since, to devise a remedy for the injurious effects of that material upon his ore and was advised to give his attention to it, not as an iron ore, but as a substance well suited for the manufacture of copperas. Since that time he has sold large quantities of it for this purpose, in Philadelphia, at seven dollars and a half the ton.

"The several layers in this mine vary much in their dimensions; but their respective average thicknesses may be stated thus:

Soil	2	feet.
Brick clay and gravel	25	"
White clay, pieces of slate, and red clay	3	"
Very dark clay	4	"
Iron ore and copperas mineral from 6 to 18 feet	12	"
Ferruginous sand	2	"
	48	feet.

"Generally the pure iron ore, and the sulphuret of iron or copperas mineral, occur separately, or in different layers of the same stratum, the sulphuret in the lowest position."

Three other sections are given in Rogers' 1858 Report (p. 265) as follows:

"A mile W. of Trexlerstown, and half a mile N. E. from Breinigsville, occurs the noted mine of copperas earth and iron ore, worked, at the period of our first surveys, by Nathan Whiteley. Some borings had been made here by the proprietor, the results of which may serve to illustrate this interesting and singular deposit:

Result of Borings at the Iron and Copperas Mine near Trexlerstown.

No. 1. West of present workings.		No. 2. Further Westward.		No. 3. Eastern Boring.	
Feet.		Feet.		Feet.	
30	Clay and gravel.	15	Gravel and clay.	14	Clay.
4½	Iron ore.	1	Iron ore.	8	Iron ore and clay.
7½	Clay.	15	Clay.	9	Iron ore.
2	Black clay.	5	Slate.	3	Clay.
12	Sulphuret of iron.	6	In clay.	2	Copperas earth.
5	Iron ore.	9	Pipe ore and clay.	2	Do. and black clay.
	Bottom of boring.	4½	Clay.	2	Do. and white clay.
			Bottom.	8	Brown clay and iron ore.
				2	Rock-iron ore.
				8	Clay.
					Bottom."

Under present conditions it does not appear feasible to mine pyrite at any of the localities where it is known to occur.

OCHER

Ocher is one of the minor mineral products of Lehigh County. It has been produced over a long period of years from several localities. but the production has always been small and spasmodic. The material is low grade.

The term "ocher" has been used in so many different ways that, at the present time, there is considerable confusion in regard to its correct usage. No sharp line has been drawn between ochers and iron ores, and at one time an important suit in the courts of Cuba involving the ownership of extensive iron deposits hinged upon the definitions of these two substances. Certain it is, however, that they may possess similar qualities and that one may pass into the other by slight gradations. Certain materials are undoubtedly applicable either to the production of pig iron or the manufacture of paints, while on the other hand certain substances that are suitable for paint possess little or no value for the production of iron and vice versa.

In this country the term ocher has been applied to red, yellow, and brown earths that owe their color to oxides of iron, but in Spanish the term is applied only to the yellow earths. The yellow ochers are so much more abundant, however, that when the term is used without any modifying term it is generally understood to refer to the yellow ochers only.

The physical character of all ochers is the same, viz., loose, earthy, and pulverulent. The chemical composition varies, however, according to the different colors.

Yellow or ordinary ocher contains as its essential constituents clay (hydrated aluminum silicates) as the base and limonite (hydrated ferric oxide) as the coloring matter. Some materials high in iron oxide and low in alumina and combined silica have been classed with the ochers by some writers but there is now a decided tendency to eliminate from the ochers those substances that are unusually high in iron. Materials containing over 30 percent of iron are classed with the iron ores and those of lower iron content are called ochers provided they have the proper physical character and the chemical composition agrees in other respects. Thus ocher is essentially a variety of clay and is so described by Pirsson [1] who says:

"When pure it (clay) is white, but it is generally colored red or yellow by iron oxides, forming red and yellow ochers." A report of the Scientific Section of the Paint Manufacturers Association of the United States [2] says "ocher is an hydrated ferric oxide permeating a clay base. It has a specific gravity of about 3.5, and a decidedly golden yellow color. A good quality should contain 20 percent or over of iron oxide."

Yellow ocher is found in nature and cannot be produced artificially. It is either marketed in its raw condition or burned to form red ocher, the burning process converting the iron oxide into the anhydrous state.

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[1] Rocks and Rock Minerals, p. 328.

[2] The Properties and Structure of Certain Paint Pigments. Bulletin No. 29, p. 18, 1910.

Red ocher differs from yellow ocher only in the condition of the iron. In the former the iron is in the anhydrous form while in the latter, as stated above, the iron is combined with water. Red ocher is found in nature and is also produced from yellow ocher by burning.

Ocher has been produced at several localities in Lehigh County. Most of it has been hauled to local paint mills where it has been used by itself as a paint pigment or blended with products from other districts. Some has been used in the raw state for the manufacture of light yellow paint, but most has been burned and utilized for red paint.

The ocher is generally found in close association with the limonite iron ores. The descriptions of individual iron mines on preceding pages show this connection. Much ocher was encountered in the operation of these mines but in only a few instances was it recovered. Generally it was in thin layers or lenses or small pockets associated with red, white, and black clays so that it was not practicable to separate them. The limonite ore in large and small pieces was also intimately associated with the ocher. In Lehigh County the ocher recovered was generally a by-product of the iron mines. In a few places the iron ore was a by-product of the ocher mines, the larger pieces of ore being separated and marketed from time to time whereas the smaller pieces remained in the ocher, either to be washed out later or to be ground in a mill to form a constituent part of the pigment.

The mixture of the different kinds of clay from the limonite iron ore washeries was run into settling basins as waste matter. In some cases these clays were sufficiently high in iron to be regarded as ochers. They are generally known as "mud-dam deposits" and are close to the old iron mines. With no attempt to separate the other colored clays from the yellow ocherous clay, nearly all the mud-dam ochers are of low grade. Nevertheless through systematic search and careful sampling of these old deposits, places have been found where paint manufacturers have obtained useful material. The best grade ocher is found at the far side of the deposit, since the coarse, heavier particles of quartz and rock were dropped close to the log washer. The market demands for this grade are small and probably an abundance still remains in these mud-dam deposits.

The origin of the ochers of the region is the same as that of the limonite iron ores discussed on previous pages. The iron ores merely represent a higher concentration of the limonite and consequently a different physical character.

Mining methods[1]

The ocher has been mined both by open cut and by shafts. The former method was used wherever ocher lies within 10 to 15 feet of the surface, and shafts were sunk where it lies deeper. The pockety character of the ore and the uncertain market for the product did not justify elaborate equipment. In some mines little timber was used except in shafts and main drifts, and mines caved soon after operations ceased. If much water was present the squeezing action of the clay required extensive timbering even in the small stopes.

In most mines the ocher extends in a somewhat definite band. Drifts following the ore bodies were run from the shaft in both directions. If a pocket of ore extended upward, overhead stopes were opened. Drifting followed stringers or pockets of ore; when they died out the drifts were run in almost any direction but mainly parallel to the course of the principal bodies where the ore seemed to be so arranged. The ore was trammed to the shaft in wheelbarrows and hoisted in buckets to the surface, where it was washed and prepared for shipment. The power necessary for hoisting, running the washing plant and grinding machinery, and operating the pumps was furnished by a small steam plant. Cornish pumps took water from the mines or near-by wells for washing the ore.

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[1] Miller, B. L., The Mineral Pigments of Pennsylvania: Topog. and Geol. Survey of Pennsylvania, Report No. 4, pp. 25-26, 1911. Present tense changed to past tense in some places.

Preparation for market[1]

As the ore came to the surface it was mixed with clay, nodules and fragments of limonite, and pieces of chert. The clay could not be removed by washing, but the hard particles could. The common log washers were very effective; the ocher and clay were washed out at the lower end while the hard particles were pushed out at the upper end. Most of the iron ore was picked out by hand and thrown to one side, where it accumulated until there was enough to ship to some near-by furnace.

The ocher and clay were washed into a series of settling troughs, which were inclined slightly so that the water passed through them rather slowly. The current was further retarded by baffleboards, behind which the coarser particles settled. The coarsest sand settled first; the sediment diminished in size in each trough until the last, where the little sand present was extremely fine. Thence it passed to settling ponds formed by digging a few feet in the surface and throwing up excavated material to form an embankment. These settling ponds were roughly rectangular and varied in size, probably averaging about 40 feet in length, 25 feet in width, and 3 to 4 feet in depth. They were frequently arranged in series so that the finest material passed from the first pond into the second. The overflow from the last pond was carried off through a pipe. The material could be graded by turning the best grade of ocher brought to the surface into one pond and that having a large admixture of clay into another pit. When a pond was full the surplus water was allowed to evaporate. Evaporation might require a few weeks to several months, depending on the weather. When the ocher was dry enough to be shoveled readily, it was dug and hauled in wheelbarrows to the drying sheds, where it was placed on long open shelves for final drying. In a few mines steam-drying sheds were used, but most of the ocher was air-dried. From the drying sheds the material either was hauled direct to the railroad for shipment or was ground in French buhr mills and shipped in bags or barrels.

Ocher has been dug from mud-dam deposits where the amount of sand was smallest, and washing was not necessary. In some of these deposits ocher was obtained of almost as good quality as that carefully purified by washing. The ocher, however, is likely to contain more clay and sand than do prepared ochers; washing may then be necessary to remove the sand. Several layers of fairly clean ocher are usually present in extensive mud-dam deposits.

Descriptions of Individual Properties

In recent years there has been little production of ocher in Lehigh County so that little can be added to the descriptions published by the writer in 1911 (Miller, B. L., 1911).

MINE OF THE VICTOR MINING COMPANY, WESCOSVILLE

The Victor Mining Company, with offices at 140 Maiden Lane, New York City, and also in Alburtis, opened an ocher mine ¾ mile south by west of Wescosville on the farm of Hiram Hiskey. The shaft sunk during the summer of 1910 was located beside an old open-cut limonite iron mine that was abandoned many years ago and close to the spot where a decade previously another shaft was sunk to obtain ocher for the Bass Paint Company then operating a mill at Alburtis. The earlier attempt was not successful and the mine was soon abandoned.

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[1] Miller, B. L., The Mineral Pigments of Pennsylvania: Topog. and Geol. Survey of Pennsylvania, Report No. 4, pp. 25-26, 1911. Present tense changed to past tense in some places.

The shaft was 52½ feet in depth, and according to Mr. M. H. Shankweiler, General Manager, the following materials were penetrated in sinking it:

	Feet
Light yellow clay containing some streaks of red clay and occasional pieces of iron ore	35
Layer of limonite iron ore in clay matrix	6
Gray clay	2
Ocher containing much fine iron ore and some large geodes of hard limonite	9½
Gray clay not penetrated.	
Total	52½

Drifts were run in the ocher bed at the bottom of the shaft a short distance only. The material was hoisted to the surface by a windlass and the coarse iron ore picked out by hand and the ocher with the fine limonite particles was hauled to the mill of the Prince Metallic Paint Company at Alburtis.

The ore and clay occupy a solution depression in the limestone and the bottom of the shaft probably was near the bottom of the residual material, as a well nearby struck limestone at a depth of about 50 feet.

All the material mined was sold to the Prince Metallic Paint Company at Alburtis for use in the manufacture of metallic paint. It was not washed but fed directly into a rotary kiln 30 feet in length and 30 inches in diameter rotating at a speed of one revolution in 55 seconds. The fuel used was bituminous coal, which was burned in a furnace at lower end of kiln. After burning the material which acquired a dark red color was ground very fine in a Sprout-Waldron vertical grinder and then packed in bags holding from 70 to 100 pounds, in kegs holding 100 pounds, or in barrels holding 300 pounds. The material was sold under the trade name of "Single Label Metallic Paint."

OCHER MINES 1½ MILES N. W. OF ALBURTIS

For about 15 years ocher was mined on the adjoining farms of Samuel Butz and Reuben Deysher, 1½ miles N.W. of Alburtis, but the supply having been practically exhausted they were abandoned about 1908. The material obtained on the farm of Mr. Deysher was mainly hauled to a paint mill at Merztown, while that from Mr. Butz's farm was taken to Alburtis, where it was used in the manufacture of Prince's Metallic Paint.

The material obtained was similar to that occurring in the mine previously described and was used in the same way. The larger harder pieces of limonite were picked out and the remaining mixture of ocher and fine limonite burned without washing and later ground.

The mines were worked both by open cut and by shallow shafts, some of which were 40 feet in depth. Little timbering was necessary. The ore and associated clay represent the residuum left when the soluble portion of the limestone was removed. No rock in place is exposed in the region nearby and the writer could not learn whether any limestone was encountered in the workings. The shafts have caved.

BEAR BROTHERS PLANT 1½ MILES N. W. OF BREINIGSVILLE

The ocher mine and mill of Bear Brothers located 1½ miles N.W. of Breinigsville was not in operation when visited in August 1910. The mine was worked by a shaft now filled with water located by an extensive abandoned open-cut limonite iron mine. This mine (68) is described on a previous page.

Prime described another mine in the same vicinity and states that "the mud from the mud-dam, which is ocher-yellow in color, is carefully dried and then sent as ocher to the Blue Mountain Paint Company at Bethlehem. Mr. McCreath analyzed it and found

Insoluble residue	55.88
Alumina	19.40
Ferric oxide	10.57
Lime	0.08
Magnesia	1.71
Water	8.17
Alkalies	3.76
	99.57"

The iron mine is located at the contact of the Martinsburg shales and the underlying limestones. The plant consisted of a boiler and engine room with machinery to hoist the ocher up the shaft which had two compartments and for pulling the loaded cars up an incline from the shaft to the log washer. From the log washer the ocher was transported to settling basins in the pits of old open cut iron mines. Thence after the preliminary stage of drying, it was taken to open air drying sheds. The dried ocher was ground in a Sprout-Waldron mill, then elevated, and by means of a screw conveyor carried to tubes, down which it passed into barrels or sacks for shipment. Some of the ocher was burned in a small rotary kiln, but most was shipped as raw ocher. The water was pumped from the mine by a Cornish pump and this water used in the log washer.

MUD-DAM DEPOSIT 1 MILE N. E. OF TREXLERTOWN

On the farm of Jerry Gramme, 1 mile N.E. of Trexlertown, ocher was dug from an old mud-dam deposit beside an immense abandoned open-cut limonite iron mine now filled with water. The deposit is about 15 feet in depth and covers more than 2 acres. At the end of the old pond farthest removed from the point where the water from the washer carrying the suspended sand, fine ore, ocher, and clay entered, the ocher is fine and no doubt large quantities of fairly clean material can be obtained. Certain layers have a deep yellow color and these are the ones which were worked. The ocher was hauled to the mill of the Prince Metallic Paint Company at Alburtis, where it was crushed, ground and shipped as raw ocher.

The deposit of iron and associated ocher probably occupy a depression in the Beekmantown limestone, although no exposures of rock in place were observed in the vicinity of the mine.

MUD-DAM DEPOSIT 1½ MILES N. E. OF TREXLERTOWN

One and one-half miles N.E. of Trexlertown, on the farm of William J. Smith, ocher has been dug in an old mud-dam deposit produced from the ore washings when a large open pit limonite iron mine on the opposite side of the road was operated. The material differs from that described in the previous deposit in that it has a decidedly reddish color. It was hauled to the plant of the Prince Metallic Paint Company at Alburtis, where it was burned, crushed, ground, and marketed under the trade name of ''Terra Cotta.''

Other occurrences of ocher are given in the descriptions of individual limonite iron ore mines on previous pages, especially those of mines 181 and 182.

LIMESTONES *

Lehigh County is well provided with limestones belonging to the Cambrian and Ordovician periods. The limestone strata aggregate about 4,000 feet in thickness. They are fairly well distributed in that all except the five most northerly townships contain limestones; a few of the central ones contain only limestones as the outcropping strata.

The limestones lie within the Great Valley, which cuts across the county and contains most of the towns—Allentown, Catasauqua, West Bethlehem, Fountain Hill, Coplay, Cementon, Egypt, Ormrod, Fogelsville, Alburtis, Macungie, and Emmaus. Saucon Valley, part of which lies within Lehigh County, is floored with limestones. This is an offshoot from the Great Valley. Limestones are exposed also along Hosensack Creek in Lower Milford Township.

Table of limestones of Lehigh County

	Thickness in feet
Ordovician	
Martinsburg shales and slates overlying the limestones.	
Jacksonburg low-magnesian argillaceous limestone used in portland cement manufacture	600±
Beekmantown limestone composed of alternating high- and low-magnesian beds	1000±
Cambrian	
Conococheague (Allentown) dolomitic limestone	1500±
Tomstown dolomitic limestone	1000±
Hardyston sandstone and quartzite underlying the limestones.	

Descriptions of Individual Limestones

Tomstown limestone.—The Tomstown formation contains the oldest limestones of the county. In general they are present only along the southern margin of the limestone valley, where they overlie the Hardyston sandstone. Due to complex folding and faulting the distribution is not always normal. The position of the outcropping Tomstown strata near the base of the mountains bounding the Great Valley on the south is not favorable for exposures as the talus from the mountain slopes conceals the edges of these strata. The Tomstown formation consists of massive, hard, dolomitic and siliceous limestones interbedded with shaly layers containing practically no calcium carbonate. The Tomstown limestones have been utilized for blast furnace flux and for crushed stone.

Allentown limestone.—Overlying the Tomstown and at places differentiated from it with difficulty is the Allentown formation. This is the most widespread formation of the county and occupies most of the southern half of the limestone valley. It consists of thick to thin magnesian limestones, in which alternating beds differ greatly in their content of magnesia and silica. On a weathered surface exposing different beds this variation in the amount of magnesia results in the formation of a banded structure that can be readily distinguished at a considerable distance. On weathering those beds with the greater amount of magnesia become much whiter than those with small percentages. These limestones have been quarried in many places for lime burning, for furnace flux, building stone, and crushed stone.

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* Note: A more complete discussion is contained in the writer's volume "Limestones of Pennsylvania," published by this Survey in 1934 as Bulletin M 20. That report is still available.

Beekmantown limestone.—The Beekmantown limestones generally occupy the greater portion of the northern half of the limestone valley. They consist of interbedded low- and high-magnesian limestones. Some beds are sufficiently low in magnesia to be used in portland cement manufacture, although the interbedded high magnesian stone renders it difficult to avoid a mixture. These limestones have been used mainly for lime burning, for flux, for crushed stone and for building purposes and to a minor extent for cement manufacture.

Jacksonburg limestone.—The most impure limestones of the county and yet the most valuable constitute the Jacksonburg formation. These are discussed under Cement.

Uses

The limestones of Lehigh County, exclusive of the argillaceous variety described under Cement, are widespread and have been quarried in scores of places. It is only a slight exaggeration to say that a quarry has been opened on every farm in the limestone areas.

The limestones of the county have been used for building purposes (described under Building Stones), for the manufacture of lime, for flux, and for crushed stone. The earliest use was for building stone and for lime. The first settlers opened small quarries where they got stone for their own use to burn lime for mortar or for fertilizing the soil. Those farmers without limestone on their own property sometimes hauled the stone from their neighbors' farms and burned it in small kilns near their residences.

When the iron mines were opened in the region and furnaces were erected there was a demand for fluxing stone, and several quarries of considerable size were operated for this purpose. With the advent of portland cement and the construction of concrete roads, bridges, and buildings, the demand for crushed stone for aggregate developed. Each of these uses has followed more or less in the order named and at the present time crushed stone is the most important. Some quarries have at different times been worked for each of the uses mentioned but seldom for more than one at the same time.

HIGH- AND LOW-MAGNESIAN LIMESTONES

Inasmuch as the amount of magnesia present in the limestones renders them either fit or unfit for specific purposes it is useful to have a quick method of roughly determining the composition without a chemical analysis.

The distinctions between high- and low-magnesia limestones, which are important in field examinations and find application in the study of the Tomstown, Allentown and Beekmantown formations of Lehigh County, have been described by the author in a previous publication.[84]

The low-magnesia limestones are soft and easily broken in comparison with the highly dolomitic ones, so that a geologist can with practice rather closely approximate the magnesian content by the hardness and toughness of the stone when struck with the hammer. The dolomitic stones are also finer grained and more compact than the less magnesian ones of the same region.

High- and low-magnesia limestones can readily be distinguished on weathered surfaces. The high-magnesia limestones contain numerous straight cracks running in all directions, along which vein material has commonly been deposited in layers so extremely thin that the freshly broken surface scarcely indicates their existence. On being exposed to the weathering agents these cracks furnish access to dissolving fluids and the weathered surface of the rock looks as though someone had hacked the stone with a steel cutting implement. Where high- and low-magnesia limestones are interbedded, the contrast on weathered surfaces is striking.

The dolomitic limestones likewise have many more gash veins of quartz and calcite than do the purer limestones. There is also a greater amount of quartz in the vein fillings of the dolomites.

Limestones for lime.—More limestone quarries in Lehigh County have been opened to get stone for burning than for any other purpose. Most of them are small and are now filled with rubbish and the kilns nearby are in ruins. Almost every clump of trees in the fields conceals one of these abandoned quarries. Of course, many of the quarries were opened along the stream bluffs. Years ago it was the common practice for the farmers to quarry and burn the stone during seasons when there was little work to be done in the fields. The kilns were constructed of field stones, many of glacial origin, and wood was used for fuel. The burning was not very efficient and the limed fields now contain pieces of chalky-white, partially-burned stone that may have lain there for many decades. Students have been puzzled by these limestone fragments, so unlike the other limestones in appearance. The farmers felt that it was profitable to add lime to the soil every three to five years and by a definite program one-third to one-fifth of the farm would be limed each year.

Although the great bulk of the lime produced was used for improving the soils, at all periods the lime needed to supply the local demand for mortar also came from these same kilns.

Gradually the belief in the necessity of liming soils waned as fuel became scarcer and labor more expensive, and the farmers ceased to manufacture their own lime. In a few well-favored places larger kilns were erected, coal was shipped in for fuel, and larger production resulted. The product was sold for several miles about and even shipped considerable distances. As it came into competition with lime produced in other sections, more care was taken in its manufacture, both in the selection of the stone and in the burning.

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[84] Miller, B. L., Limestones of Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. M 20, p. 11, 1934.

The early product naturally was of variable quality. The farmer burned whatever stone he had on his property. Some of the Tomstown limestones are high in silica and alumina and almost all others are highly magnesian.

Lime is not produced commercially at present in Lehigh County. However, from time to time some old kiln is restored and a small quantity of stone burned for local use. Formerly there were many fairly large lime plants in the east, south, and southwest parts of Allentown, at Limeport, and in the vicinity of Catasauqua. Most of the quarries furnishing the stone are now idle or are being worked for crushed stone.

There are few places in the county where the highest grade of lime could be produced. In general the silica content is high and the magnesium carbonate is too high for high-calcium lime and too low for high-magnesium lime. Large, well-equipped plants in other parts of the State supply the local demand.

Limestones for flux.—When the local iron ores were being mined and smelted in the furnaces scattered along the Lehigh River, in the Saucon Valley and elsewhere, many limestone quarries were operated in regions nearby to supply the necessary fluxing stone. Some of these were worked for fifty years or more and are of large size. Practically all the stone used was highly magnesian. The silica and alumina also were high in some quarries. The proximity of the quarries to the furnaces and the consequent low transportation costs generally made the use of rather poor stone profitable.

Nearly all the quarries from which stone was obtained for flux were along the railroads, and spurs were built into the quarries. In many places better material might have been obtained elsewhere, but the cost of hauling the stone to the railroads was prohibitive.

Although the limestones have been used extensively for flux, some objectionable features have inconvenienced the operators, the worst of which is the presence of layers high in silica. Most of the furnace operators prefer limestones that contain strata with less than 4 percent silica, and where shaly or sandy strata are interbedded with the limestones it is necessary to separate these beds as waste rock. The presence of solution cavities filled with clay, which are common in regions where the rocks have been deformed or shattered by earth movements, is equally objectionable. Clay fills deep solution pockets in the surface in places, and the removal of this overburden greatly increases the cost of quarrying.

Rock of quite different composition was obtained from a single quarry, so that it is difficult to select a typical analysis. The following analyses of stone actually used by local furnaces represent the best grades that could be obtained. These are copied from the analysis book of the Thomas Iron Co. and are furnished by Dr. B. F. Fackenthal, Jr. Many other analyses of similar character are available.

Analyses of Lehigh County limestones used for flux

	Highest SiO_2	Lowest SiO_2	Average SiO_2	$CaCO_3$	$MgCO_3$	Al_2O_3	Fe_2O_3	Phos.	S.
1.	4.10	1.40	2.86						
2.	1.10	1.10	1.10	53.78	42.67	1.64	.39	.01	.02
3.	3.70	1.10	2.39	51.84	43.49	1.29	.52	.008	.031
4.	3.80	1.00	1.99	51.96	43.18	1.35	.77	.009	.033
5.	4.90	1.30	2.26	51.97	43.37	1.23	.59	.011	.018
6.	4.50	1.90	3.03	51.32	42.69	1.25	.65	.010	.029
7.	3.70	1.50	2.77	51.82	42.48	1.86	.41	.010	.020
8.			1.36	53.43	43.39	.88	.94		
9.			8.12	48.68	38.36	2.53	1.31		
10.			1.26	54.14	44.98	.49	.55		
11.			2.75	52.72	42.46	1.34	.74		
12.	8.10	4.70	4.70	48.12	42.54	2.07	1.18	.016	.045
13.	6.00	2.80	4.53	49.44	42.51	1.97	.88	.013	.015
14.	10.50	2.10	4.00	50.33	41.54	2.80	.57	.027	.012
15.			13.04	76.12	7.18				
16.			8.52	80.35	8.00				
17.			8.98	84.95	2.67				
18.			18.72	69.06	4.32				
19.			9.05	52.71	36.91				
20.			9.32	84.33	2.51				
21.			1.20	52.94	44.50	.66	.53		
22.			16.60						
23.			9.10	70.05	17.60				

1. John L. Trexler quarry, East Allentown.
2. Ziegenfuss quarry, East Allentown. Main line N. J. C. R. R.
3, 4, 5, 6, 7. Ferdinand Eberhart, on C. & F. R. R. at West Catasauqua.
8, 9, 10, 11. Aaron Dankle's land, C. & F. R. R. near Lock Ridge.
12, 13, 14. Spring Creek quarry, used at Alburtis Furnaces.
15. Frankenfeld quarry near Siegersville.
16. W. J. Bear, from his property on line of Ironton R. R.
17. Trexlertown.
18. Jordan Bridge on C. & F. R. R.
19, 20. Cave from artesian well at Lower Catasauqua.
21. John L. Trexler's land, East Allentown.
22, 23. Mickey's land, cut on extension of Ironton R. R. from West Coplay to West Catasauqua.

Limestone for crushed stone.—As in other parts of the State, the Cambro-Ordovician limestones of this section have been used extensively for roads and for concrete aggregate. Except for occasional shaly bands, practically all the stone will meet the rigid specifications of the State Highway Department. Scores of quarries have been opened to supply local demands but most of them are of moderate size. Some fairly large quarries have been developed near the larger boroughs to supply the demands for concrete material.

The largest amount of crushed stone in Lehigh County has been produced in the vicinity of Allentown. Along the Central Railroad of New Jersey on the east side of the Lehigh River, a large amount of stone has been quarried in recent years for crushed stone. Previously these quarries furnished stone for burning to lime. These quarries are now closed and may not be reopened because of their proximity to the railroad tracks. Several similar openings in the south part of Allentown were once worked, but are now abandoned.

In the north part of Allentown, North Seventh Street, the Allen Quarries Co. long operated a quarry for crushed stone. A small amount of fluxing stone was sold. This quarry in dolomitie limestone of the Allentown formation, is about 300 feet long and 250 feet wide, with a working face about 60 feet high. The beds strike N.84°W. and dip 45°SW. There are several different kinds of stone in the quarry. The most abundant is a dark blue, compact dolomite. There are a few shaly beds. Fine oolite, edgewise conglomerate, and black to almost white flint nodules are common. The stone has been badly shattered in places and now contains many veins of calcite and quartz. A few layers show grains and even small rounded pebbles of quartz. The stone is hard and well adapted for use in concrete. An analysis made in the laboratory of the Lehigh Portland Cement Co. showed 64.42 percent $CaCO_3$, 41.03 $MgCO_3$, and 2.02 SiO_2. The daily output is about 300 tons.

The C. H. Ziegenfuss Co. has for many years been working a quarry in southwest Allentown at 20th and Fairview Streets. The stone is a part of the Allentown formation and is similar to the dolomite worked by the Allen Quarries Co. From this quarry at one time stone was obtained for flux and for lime burning, but at present only crushed stone is being produced. The annual capacity is given as 125,000 tons.

The Alburtis Stone and Sand Co. worked a quarry along a branch of the Reading Railroad about a mile north of Alburtis. The face is about 40 feet high in one place. The stone is dolomitic and belongs to the Conococheague (Allentown) formation. The beds are fairly massive, although somewhat shattered. They strike N.59°W. and dip 10°NE. The plant was equipped with crushers and screens. An analysis made in the laboratory of the Valley Forge Cement Co. is as follows:

$CaCO_3$ 54.42, $MgCO_3$ 42.33, $Fe_2O_3+Al_2O_3$ 0.90, SiO_2 2.50.

About three-fourths mile northeast is an old quarry belonging to John A. Walbert recently worked for highway stone. Previously for about 30 years this quarry was worked for flux for the Lock Ridge furnace of the Thomas Iron Co. The stone is a dolomite of the Allentown formation. The quarry face is about 500 feet long and 70 feet high.

Frank A. Kuntz had a small crushed-stone quarry about half a mile south of Center Valley. The stone is a dolomite containing over 40 percent $MgCO_3$. At one time the annual output was 3,000 tons crushed stone, 1,000 tons limestone sand, 100 tons pulverized limestone, and 10 tons poultry grits.

The Lehigh Stone Co. is working a quarry for crushed stone about half a mile south of Ormrod. It is an extension of the Lobach quarry, which was worked for several years to obtain high-grade limestone for some of the cement plants. At one time the Giant Portland Cement Co. mined limestone here. This band of good stone ranges from 35 to 150 feet in width and contains from 85 to 94 percent $CaCO_3$. Overlying the high-calcium stone there are dark colored, extremely hard, mainly thin-bedded dolomites, said to contain more than 40 percent $MgCO_3$. The main quarry has been developed in this type of stone. The opening is about 400 feet long, with a working face 300 feet wide and 70 feet high. The lower beds exposed have been greatly folded, but the upper ones exposed are fairly regular with a strike of N.57°E. and a dip of 19°SE.

Limstones for cement.—Since the Jacksonburg formation in certain places contains too small an amount of $CaCO_3$ for the manufacture of portland cement, several companies have been compelled to bring in some high-grade stone from other places. Naturally, they have searched for stone of similar quality in proximity to their operations. Some suitable stone has been obtained in the Beekmantown, which is in contact with the Jacksonburg, but interbedding of this high-grade stone with magnesian strata has made their separation difficult. Since 1938 a quarry in Berks County has been producing low-magnesian stone from beds thick enough to permit steam shovel operations. So far, no similar occurrence has been found in Lehigh County. With some Beekmantown limestone containing upwards of 90 percent $CaCO_3$ and very little $MgCO_3$, it is only natural that money be spent in search of workable thicknesses of this kind of rock. The writer knows of several places where diamond drilling was done for this purpose. In each case it was found that the interbedding of the high-calcium and the dolomitic limestones made it impracticable to open a quarry for low-magnesian stone.

Additional analyses of Cambro-Ordovician limestones in Lehigh County

	1	2	3	4	5a	5b	5c	5d
$CaCO_3$	—	52.08	51.60	51.73	—	—	—	—
CaO	27.8	—	—	—	18.23	28.33	27.44	28.10
$MgCO_3$	—	41.29	42.60	45.35	—	—	—	—
MgO	18.01	—	—	—	19.20	19.79	18.33	19.56
SiO_2	8.97	3.80	3.30	1.20	6.40	3.89	8.91	6.75
Al_2O_3	—	1.12	1.75	0.65	1.39	1.40	2.31	2.75
Fe_2O_3	—	0.79	0.52	0.66	—	—	—	—

	6a	6b	6c	7a	7b	8	9	10
$CaCO_3$	53.20	51.36	53.25	51.920	47.890	49.316	83.632	70.750
$MgCO_3$	41.30	39.72	37.10	41.071	39.585	40.463	5.462	15.256
SiO_2	2.32	4.70	4.42	5.650	11.260	8.980	7.850	11.070
Al_2O_3	1.50	2.68	3.17	—	—	0.70	—	.860
Fe_2O_3	—	0.92	1.11	—	—	—	—	—
S	—	0.026	0.026	trace	trace	—	—	—
P	0.010	0.012	.010	.011	.021	.006	.026	.019

1. Tomstown limestone. Morey farm, ½ mile southwest of Center Valley. Analysis by Bethlehem Steel Co.

2. Tomstown limestone. Ackers quarry, East Allentown, a short distance northeast of bend in Lehigh River. Analyzed by Bethlehem Steel Co.

3. Tomstown limestone. New Jersey Zinc Co. quarry, along Lehigh River just north of East Allentown. Analysis by Bethlehem Steel Co. Material used for flux at Palmerton plant of New Jersey Zinc Co.

4. Allentown limestone. Hardners quarry along Little Lehigh Creek, Allentown. Analysis by Bethlehem Steel Co.

5. Beekmantown limestone. Outcrops at Ueberroth pit of New Jersey Zinc Co.'s zinc mine ½ mile north of Friedensville. Analysis by Bethlehem Steel Co.

6. Beekmantown limestone. Eberhart's quarry, west side of Lehigh River, opposite Catasauqua, just north of junction of Coplay Creek and Lehigh River. a Analysis by the Bethlehem Steel Co. b and c. Analysis by the Thomas Iron Co. b represents the average of 183 cars shipped to the Thomas Iron Co. during the first half of 1920 and c the average of 166 cars shipped during the latter half of 1920.

7. Beekmantown limestone. Thomas Iron Co.'s quarry, ¾ mile north-northwest of Alburtis. a. Limestone, hard, compact, bluish gray. b. Limestone, compact, highly crystalline, and bluish gray. (Pa. Second Geol. Survey Report M, p. 76.)

8. Beekmantown limestone. Mary Kohler quarry, ¾ mile west of Whitehall station, L. V. R. R. Brecciated limestone; various shades of blue and gray. (MM, p. 309.)

9. Beekmantown limestone. Ironton Railroad Co.'s quarry, 1 mile southeast of Ironton. Hard and compact; bluish gray. (MM, p. 310.)

10. Beekmantown limestone. Edward Guth quarry, at Guth's Station, 4½ miles west of Catasauqua. Fine grained; dark blue, with slaty structure. (MM, p. 310.)

Additional analysis of Cambro-Ordovician limestones in Lehigh County (Continued)

	11	12a	12b	13	14	15	16
$CaCO_3$	56.220	51.558	86.036	51.603	48.630	74.05	69.00
$MgCO_3$	31.201	35.216	4.594	32.917	40.410	4.09	5.70
SiO_2	10.980	10.750	8.400	13.490	9.240	12.66	19.82
Al_2O_3	.300	.140	.065	—	—	5.19	5.40
Fe_2O_3	—	—	—	—	—	1.87	
S	—	—	—	.147	.005	—	—
P	.005	.018	.016	.012	.012	—	—

11. Beekmantown limestone. Thomas Iron Company's quarry, at Guth's Station. Fine grained, bluish gray, with some quartz. (MM, p. 309.)

12. Beekmantown limestone. Eph. Wenner quarries at Jordan Bridge of the Catasauqua & Fogelsville R. R. 4½ miles northwest of Allentown. Leased by Crane Iron Co. a. "Hard limestone," fine-grained; hard and brittle; spotted with pyrites; bluish gray. b. "Soft limestone." Comparatively soft, fine grained, dark blue, with laminated structure. (MM, p. 309.)

13. Beekmantown limestone. Mrs. Kuhn's quarry, 1½ miles northeast of Trexlertown. Limestone, compact, siliceous, light bluish gray. (M, p. 76.)

14. Beekmantown limestone, Frantz quarry, 1½ miles northeast of Trexlertown. Limestone, hard, siliceous, dark blue. (M, p. 76.)

15. Jacksonburg cement rock. Whitehall Cement Company's quarry, Cementon. Analysis by Whitehall Cement Company.

16. Jacksonburg cement rock. Typical analysis of stone in quarry No. 2, of Coplay Cement Manufacturing Co. at West Coplay. Analysis by the company.

CEMENT

The most valuable mineral deposits of Lehigh County, with the exception of the soils, are the argillaceous limestones of the Jacksonburg formation. These limestones are present in several different places in Whitehall, North Whitehall, Upper Macungie and Upper Saucon townships. The most important area extends across the Lehigh River from Northampton County from Cementon to Ormrod. Here are the major cement operations of the county. Another area near Fogelsville furnishes stone for a cement plant. Other smaller areas are located near Trexlertown and in the Saucon Valley. The patchy distribution of the Jacksonburg in Lehigh County forms a decided contrast to the continuous band that extends across the entire breadth of Northampton County between the Lehigh and the Delaware rivers. This irregular distribution is explained by the overlapping of the Martinsburg shales and by profound faulting. The same discontinuity occurs in Berks County.

The cement district of the county forms a part of the "Lehigh District" which includes the cement plants of Berks, Lehigh, and Northampton Counties, Pa., and Warren County, N. J. All of them obtain the bulk of the required stone from quarries in the Jacksonburg formation, although several must bring in some higher-grade limestone from other places to obtain the proper mix. This "Lehigh District," where the first portland cement in the United States was made, still maintains its position as the foremost cement region in the world.

History of the Cement Industry in Lehigh County

As in other regions the manufacture of natural hydraulic cement preceded that of portland cement. In New York the construction of the Erie Canal in 1818-19 led to the discovery of natural hydraulic cement rock, and in this region the digging of the canal of the Lehigh Coal & Navigation Co. (1826-30) accomplished the same result. Rock suitable for hydraulic cement was found just above Lehigh Gap, where Palmerton is now located, and also at Siegfried's Bridge (now Northampton). The rock at Lehigh Gap of Helderberg age seemed to be preferable, and a cement mill was built there under the direction of the company's engineers. This plant was operated by Samuel Glace from 1826 to 1830 and furnished material for many of the canal locks. When the best cement rock near Lehigh Gap was exhausted, material was quarried about six miles east of the gap and hauled to the plant. However, in 1830 it was decided to abandon the mill and to erect a new one at Siegfried's Bridge, where suitable rock was known to be obtainable. In a small pamphlet by William H. Glace, entitled "A Narrative of Hydraulic Cement Mined in the Lehigh Valley," the following description is given:

> Capt. Theodore H. Howell, residing at Siegfrieds, informed me that when he came there in 1837 there were four kilns erected and in operation. They were known as draw kilns, fire being placed in the eye at the bottom of the kilns, drawn at the bottom and hoisted up an incline plane or tramway and emptied into a hopper, where the stones were crushed by machinery shaped like a corn crusher, then dropped down and ground by burr millstones, then placed in boxes or trays with handles, then transported in scows to points on canal where needed. These scows were drawn by mules with a steersman on a platform on the rear of the scow, having a large tiller, fifteen feet long, ending in a large blade or paddle, which tiller was fastened on a socket at the balance point, and thus lifted with little exertion at will, and when in use was a powerful means to turn the boat in any direction wanted. At that time the capacity of this plant was ten barrels per day.
>
> The canal, from this place down to the Allentown dam, was through a farming community, and the loam and clay on the banks of the canal were vulnerable places for the muskrats, which were plentiful. They seemed to be busy constantly and would in a short time make a hole in the embankment, which if not attended to would empty the canal and stop transportation.
>
> The method to remedy this was an alarm given by the bank watchman, the scow or cement boat sent for, which with the mules trotting, a man in front blowing a horn, giving them the right of way, the steersman on his platform at the rear, meanwhile the workingmen were emptying the trays (which had been covered with a tarpaulin), on the bottom of the boat, mixing it with gravel and sand, dipping up water from the canal and making the concrete. As soon as the leak was reached a small coffer dam was built around it, water emptied and the concrete applied, stamped with wooden stampers in the break, the frame work removed as soon as grouting hardened. In those years Samuel Glace was supervisor of the canal from Slate Dam to Allentown Dam, in addition to the cement work at Siegfrieds until 1841.

Natural cement continued to be manufactured from the Jacksonburg limestone in the vicinity of the present borough of Northampton. M. S. Henry reports the conditions there in 1860.

> On the eastern side of the river, directly opposite the village (Whitehall, now Cementon), are the extensive Hydraulic Cement Works of E. Eckert

& Co. These works have been in successful operation for a number of years, and the cement (which is mined in the neighborhood) is said to be equal in every respect to the celebrated Rosendale cement.

Until 1872 the manufacture of natural cement at this place was continued on a small scale. That year the original plant was leased by General J. Selfridge and more kilns were constructed and the production increased to 200 barrels per day. The company became the Old Lehigh Cement Co. A new quarry was opened on the Hokendaqua Creek about a mile east of the plant. Market conditions were so poor that for the next five years the plant was idle most of the time.

Another natural-cement plant, called the Allen Cement Co., was built nearby on Hokendauqua Creek in 1872 and opened a quarry close to the mill.

The first cement operations in Lehigh County started somewhat later than in Northampton County. In 1866 David O. Saylor and two associates organized the Coplay Cement Company. They acquired property and in the following spring proceeded to develop it. Mathews and Hungerford (1884, p. 506) furnish the following description:

"They built two small kilns for burning the stone, and fitted up an old distillery building near Coplay Station for a grinding-mill. They at first utilized the rock in the small knobs and ridges left between the railroad cut and the river, hauling it about one mile to their works. The business, though small, was profitable, and, as soon as it was practicable to do so, the enterprising proprietors enlarged it. In 1869 they built a frame and stone mill near the small kilns, and then proceeded to erect two additional kilns, which increased the capacity of their works to about two hundred and fifty barrels of natural cement per day. In 1870 the company opened a new quarry and a slope in the greater mass of rock west of the railroad cut. In 1871 they built an addition to their mill, which largely increased the effectiveness of their operations.

"Up to this time only the ordinary, or what is called the natural cement, had been manufactured, but in 1872, Mr. D. O. Saylor, the president of the company, discovered a process by which an improved cement could be made, and secured a patent upon it. The product of this process is known as the 'Anchor Cement.'"

Prime (1878) gives the following description of Saylor's "Anchor Cement":

"This is an improved article of cement which after a trial of five years has proved itself to be equal to any American light burnt cement. It is claimed that the peculiar process employed in manufacturing it (which is patented) makes it different in its chemical nature to all other American cements. It sets rapidly, has great powers of cohesion, and acquires an unusual degree of hardness, both under water and in the air.

"Its color is a beautiful greenish gray which makes a very desirable color for building purposes. It is said to be excellent for the manufacturing of sewer and drain pipe, making smooth and uniform work, setting rapidly; therefore more pipe can be made with the same number of molds than with a slow setting cement. It is, therefore, desirable for concrete or beton for subaqueous foundations, and for piers and abutments of bridges. In a report of the engineers in charge of the construction of the Girard avenue bridge, at Philadelphia, Pa., one of the most substantial and most beautiful bridges in the country, they say that of all the different common American cements experimented with and tested for the beton or concrete for the foundations, the Anchor cement proved the strongest and most satisfactory in all respects."

Some natural cement was made on a property along the Lehigh Valley Railroad just north of the Coplay Cement Co.'s quarry where later the Atlas Portland Cement Co. (the forerunner of the present Universal-Atlas Cement Co.) first started the manufacture of portland cement, and also by another small company known as the Hercules Company, on the site of the present Whitehall Cement Manufacturing Co.'s plant.

Natural cement was made long after portland cement became dominant and only a few years ago a plant for its manufacture at Egypt was abandoned and the buildings scrapped.

Meanwhile, Saylor was carrying on experiments for the manufacture of portland cement such as was being imported from England.

Inasmuch as Saylor is known as the ''Father of the American Portland Cement Industry,'' it is of interest to know the contents of his application for a patent.

Saylor's Patent

United States Patent Office

David O. Saylor, of Allentown, Pennsylvania.

Improvement in the Manufacture of Cement.

Specification forming part of Letters Patent No. 119,413, dated September 26, 1871.

To All Whom It May Concern:

Be it known that I, David O. Saylor, of Allentown, in the County of Lehigh, State of Pennsylvania, have invented a new and improved cement; and I do hereby declare that the following is a full, clear, and exact description thereof, which will enable others skilled in the art to make and use the same.

I have discovered that some kinds of the argillo-magnesian and also argillo-calcareous limestone found along the Appalachian range, containing more or less carbonate of lime, magnesia, silica, alumina, iron, salts, and alkalies adapted to the purpose, and which are now extensively used in the manufacturing of hydraulic cement, will make, when burned to a state of incipient vitrification, so as to be agglutinated, warped, or cracked, by contraction, and some burned to cinders, a very superior and heavy hydraulic cement, weighing from one hundred and ten pounds to one hundred and twenty pounds per bushel, and in every respect equal to the portland cement made in England and imported into this country.

The ordinary cement now in our market such as Rosendale, Coplay, and other American brands, are burned with the least possible degree of heat. The stage of calcination is arrested before it fuses or is contracted; should any of it do so it is thrown away as worthless. This cement weighs seventy to ninety pounds per bushel. I propose to burn this stone to the condition above indicated. After this calcination a selection is made and the pulverulent and scarified portions of the mass are picked out and thrown away. The remainder is then passed through a crusher; then through a mill consisting of ordinary sand, or buhrstone. The manufactured material is then placed in a layer of from two to three feet thick over the floor of a cool shed and left exposed to the air for about four weeks before it is fit to use.

The stone which I use for the purpose contains the same ingredients as the composition used for making portland cement, and the products cannot be distinguished from each other except by treatment.

Having thus described my invention, I claim as new and desire to secure by Letters Patent—

1. The process of making hydraulic cement from argillo-magnesian and argillo-calcareous limestone, substantially as herein specified and described.

2. As an improved article of manufacture, hydraulic cement produced from argillo-magnesian and argillo-calcareous limestone, substantially as herein specified and described.

David O. Saylor.

Witnesses:
Edwin Albright
Augustus Weber

The Lehigh district enjoyed almost a monopoly in the manufacture of portland cement until it was discovered that an equally good product could be made from a variety of materials. Lehigh cement was shipped all over the country and much of it exported. While no other cement region occupies so favorable a position with reference to accessibility to good cement rock and fuel and proximity to great industrial centers, yet on account of freight charges the market for the cement of the Lehigh district is year by year restricted by the erection of cement plants in other sections of the country. Fortunately, however, the demand for portland cement kept pace with the increase in number of cement plants so that the district continued to prosper regardless of increasing competition.

In this region many improvements have been made since the first successful manufacture of portland cement. For a time the run of quarry was used, with the result that some companies that owned quarries in which the rock had practically the composition now looked upon as most desirable, were able to produce a better product than other companies with less suitable rock. Also few companies were able to produce a uniform product on account of the variation in composition of the rock even in the same quarry. Now, however, the chemist of each company sees that the proper mixtures are used, and the physical tests also serve as a check, so that the old hit-or-miss method has given place to the exact scientific process and the variations in the product are very slight.

The changes in mechanical process of manufacture have been equally great and each year mechanical modifications are introduced which tend to increase the output, improve the quality, and lower the cost of production. The greatest improvements have been the change from the old upright kiln to the modern rotary kiln now universally used throughout the region.

For many years the cement plants of the Lehigh District made a single kind of cement. This, however, is now changed and, effective Sept. 2, 1940, five types are recognized by the American Society of Testing Materials. Other slight modifications materially increase this number. The Society accepts the following definition of portland cement and specifies the following chemical requirements:

> Portland cement is the product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates, to which no additions have been made subsequent to calcination other than water and/or untreated calcium sulfate, except that not to exceed 1 percent of other materials may be added, provided such materials have been shown not to be harmful by tests acceptable to Committee C-1 on Cement.

Chemical requirements in maximum and minimum percent

	Type I	Type II	Type III	Type IV	Type V
Magnesium oxide (MgO), max.	5.0	5.0	5.0	5.0	4.0
Sulfur trioxide (SO_3), max.	2.0	2.0	2.5	2.0	2.0
Loss on ignition, max.	3.0	3.0	3.0	2.3	3.0
Insoluble residue, max.	0.75	0.75	0.75	0.75	0.75
Silica (SiO_2), min.	—	21.0	—	—	24.0
Alumina (Al_2O_3), max.	—	6.0	—	—	4.0
Iron oxide (Fe_2O_3), max.	—	6.0	—	6.5	4.0
Ratio of Al_2O_3 to Fe_2O_3	—	0.7-2.0	—	—	0.7-2.0
Tricalcium silicate ($3CaO.SiO_2$), max.	—	50	—	35	—
Dicalcium silicate ($2CaO.SiO_2$), min.	—	—	—	40	—
Tricalcium aluminate ($3CaO.Al_2O_3$), max.	—	8	15	7	5

It is too early to discuss the effect of these new specifications or to say whether the raw rock of the Jacksonburg formation can fulfill all the requirements. The entire cement industry is in a state of flux at the present time (Nov. 1940).

Mathews and Hungerford (1884, p. 506) continue their description of the Coplay Cement Co. as follows:

> In 1873 the company commenced the manufacture of Portland cement, in which they had reached a most satisfying success after many failures in experiment. This was named for the market "Saylor's Portland Cement." This new manufacture became very popular and necessitated greater enlargement and improvement of the works, the introduction of new machinery, and the employment of a greater force of hands.
>
> The company erected an additional kiln in 1873, two more in 1874; a pug-mill and drying-floors, necessary to manufacture, in 1875; three more kilns in 1877, six iron grinding mills, and a new steam-power, exerting the strength of one hundred and fifty horses, a new crusher, and four additional kilns. In 1882 the capacity of the Coplay Cement Works was increased still further by the erection of three kilns and two more mills. Thus seventeen kilns were brought into use, thirteen of which are employed in the work of making Portland cement, and four in making cement of the Anchor brand. The latter are of the kind known as draw kilns. About six hundred barrels of cement are made per day; the quantities of Saylor's Portland cement and of the Anchor brand being almost exactly equal. The number of employes, including coopers, quarrymen, and millhands, is upwards of one hundred and fifty. A cooper-shop was built about 1870, and twelve or more coopers employed. The stock of heading and stave lumber is brought from Maine and the hoops from New York. The milling capacity consists of four run of four-feet and eight run of three-feet buhrstones; also three iron crushers to prepare the material for the mills, and four tempering machines to temper the raw material for Portland cement. They have thirteen kilns to burn Portland and four to burn natural cement. The factory contains over nineteen thousand square feet of floor-room for spreading and drying the tempered material for Portland cement. The rooms are all heated by steam, four thousand five hundred feet of one-and-a-half-inch wrought-iron pipe and one hundred and sixty feet of six-inch cast-iron pipe being used for the purpose. There are also over twenty thousand square feet of floor-room for storing the manufactured cement, and about three hundred and seventy-five feet of iron conveyors are in use to convey the cement from the mills to the huge bins. In connection with the storage capacity at the works they have a large storehouse on the dock of the Central Railroad Company of New Jersey, at Communipaw, two hundred and fifty feet long, with a cooperage on the second floor. The cement for

> the New York market is sent in bulk to this establishment, where it is packed in barrels. . . .
>
> To the Coplay Cement Company is due the credit of having first introduced into this country the manufacturing of Portland cement on a large scale. Their peculiar advantageous position, in having inexhaustible stores of the raw material in its cheapest and simplest conditions, coupled with the advantages of shipment by rail and water, enables them to supply the article in abundance to all parts of the country at a comparatively low price. The Portland cement is recommended by the most prominent architects and engineers, and the trade generally, to be fully equal to the best foreign brands. It is of uniform quality and always reliable. Capt. J. B. Eads, the distinguished engineer, used Saylor's Portland Cement exclusively on the jetty works of the Mississippi, at New Orleans, having used upwards of thirteen thousand barrels up to this time, and recommends it highly. It is used in the river and harbor improvements and fortifications on the South Atlantic coast, fortifications on Staten Island and New York Harbor, under the superintendency and management of Gen. Gillmore, who prefers it to all others. In the Centennial Exhibition there were fourteen Portland cements, all of which were tested under Gen. Gillmore's direction, and Saylor's cement stood among the best.

The Jacksonburg argillaceous limestone is used in the cement plants of the region. At times some Beekmantown low-magnesian limestone has been mixed with the argillaceous limestone to increase the $CaCO_3$. In most cases, however, very pure limestone from the Lebanon Valley is used to make up this deficiency.

JACKSONBURG LIMESTONE

The most impure limestones of the county and yet the most valuable constitute the Jacksonburg formation. The Jacksonburg strata in this region consist of a basal member of crystalline high-grade limestone designated ''cement limestone,'' and an upper argillaceous limestone member that comprises most of the formation and is called ''cement rock.'' In some places the two are sufficiently distinct to permit separate mapping but elsewhere they grade into each other and everywhere occasional layers of the basal type are interbedded within the more argillaceous upper member.

In most places in the region the northern boundary of the cement rock can be accurately determined by an abrupt change in topography, the line of contact being at the base of the steep slopes that mark the southern margin of the slate belt. This change in slope is due to the relative ease with which the cement rock is removed by weathering, mainly solution, in comparison with the much less soluble slate.

In several places the southern boundary of the cement rock belt is also marked by a change in slope. The underlying limestone is more soluble than the cement rock, and produces more nearly level land.

''Cement limestone.''—The typical cement limestone of the region is a light to dark gray, coarsely crystalline limestone which, when freshly broken, shows lustrous surfaces of dark calcite. Less commonly it is a dark-colored limestone closely resembling in appearance the underlying dolomitic limestones. It is usually massively bedded.

Normally the cement limestone runs high in $CaCO_3$ and low in $MgCO_3$, but it varies greatly in composition. In some quarries considerable rock is obtained in which analyses show from 90 to 95 percent $CaCO_3$. Also some quarries have a few beds that contain as much as 12 percent $MgCO_3$, so much that the rock must be sorted out and discarded.

The cement limestone contains numerous fossil remains, most of which, however, are fragmentary and scarcely determinable. They are seldom apparent except on the weathered surfaces of the rocks. They are of the same kinds as those contained in the limestone layers interbedded with the argillaceous cement rock. Fragments of small crinoid stems are most abundant but locally bryozoans are very common. The bryozoans belong to several different kinds, of which the branching and the bead-like colonies are most abundant. Poorly-preserved brachiopods are also found occasionally.

The massive character of the cement limestone beds has prevented them from crumpling, but steeply dipping and overturned folds are present. The south side of the quarry of the Coplay Cement Manufacturing Company on the west bank of Lehigh River exhibits an overturned synclinal fold. The syncline is overturned to the north so that the cement limestone both overlies and underlies a mass of "cement rock" with all the beds dipping to the southeast.

Elsewhere in the region the cement limestone normally dips gently to the north or northwest at low angles and disappears beneath the cement rock. This cement limestone is of variable thickness, ranging from 100 to 200 feet.

The cement limestone grades into the overlying argillaceous limestone or cement rock by an intermediate band of interbedded, relatively pure limestone and impure argillaceous limestone strata. For that reason the two kinds of rock, although lithologically dissimilar, are regarded as constituting a single geologic formation.

At the base the cement limestone is in contact with the Beekmantown magnesian limestone.. In this region the two formations are approximately conformable, although to the eastward in New Jersey a marked erosional unconformity is shown in many places.

Glacial clay of variable thickness, with included cobbles and boulders, rests upon the cement limestone. The glacial cover interferes with the determination of the position of the formation boundaries.

"Cement rock."—The cement rock is an argillaceous limestone intermediate both in composition and stratigraphic position between pure limestone and shale or slate. In color it suggests the overlying slates and in many places it shows marked slaty cleavage. A freshly broken piece is bluish-black and shows glistening particles of sericite too fine to be individually distinguishable except as light is reflected by them. The unaltered rock breaks partially along cleavage planes and partially along bedding planes, producing hackly or, in some places conchoidal surfaces that are unlike those of either the pure limestones beneath or the slates above. As the rock weathers, however, it separates into small cleavage fragments so similar to those resulting from the decomposition and disintegration of slate that it is difficult to distinguish between a slate soil and a cement rock soil. Both are filled with thin rock fragments of a light yellowish-gray color, ranging up to 1 inch in length.

In almost every quarry the cement rock shows the effect of great compression by which it has been shattered, permitting water carrying mineral matter in solution to precipitate quartz and calcite in the open fissures and irregular cavities. In places the vein matter is pure white calcite, in other places white granular quartz, but more commonly a mixture of the two. The white veins contrasting with the black rock are very prominent in the working faces of most quarries. The veins are roughly parallel and tend to follow bedding planes, although they break across the beds in many places. Smooth slickensided surfaces coated with a soft black carbonaceous substance resembling graphite are very common on the vein walls.

Small cubes of pyrite are common near the veins and occasionally in rock where the vein material is absent. Purple and green fluorite have also been found in a few localities as vein material.

The chemical composition of the cement rock changes from bed to bed or even in the same bed within a single quarry. In some quarries the average rock contains almost exactly the right proportion of the various materials required for the best grade of portland cement. In most quarries the rock varies so that tracks must be run to several parts and the requisite mixture obtained by the proper combination of the various kinds of rock. In other quarries, however, the average rock runs too low in $CaCO_3$ so that it is always necessary to add some high-grade limestone. Some of the plants are fortunate in having quarries in the underlying cement limestone while others must bring limestone from a distance. Much limestone from Annville, Lebanon County, Pa., is used in the Lehigh district.

In many cement-rock quarries it is difficult to determine the bedding planes unless an interbedded pure limestone stratum can be found. Where these are absent the quartz and calcite veins, which, in general, follow the bedding planes, are useful in determining the structure. Almost invariably, the cement-rock strata are greatly crumpled and yet have low angles of dip. The normal direction of dip is toward the northwest beneath the Martinsburg slates, but in many quarries some beds dip in other directions.

When the region was subjected to the great dynamic forces that formed the Appalachian folds the cement-rock strata were so weak that they yielded by minor folding and faulting, resulting in local thickening of the different layers, but without producing high angles of dip. In very few places can one find the cement rock dipping more than 45° and usually the dip is much less, while in the adjoining limestone belt vertical or even overturned beds are not uncommon.

The crumpled character of the cement rock, the absence of any beds sufficiently distinct to be recognized in different openings, and the lack of any continuous or approximately continuous section across the belt normal to the strike render the exact determination of the thickness impossible. The local thickening of the beds due to compression also needs to be taken into account in any estimate of thickness.

QUARRY METHODS

The quarry methods used by the cement companies are similar throughout the district. If possible the quarry is opened in the side of a hill and the tracks run into the quarry on the level so that as the quarry is extended a greater height of quarry face is obtained. In some places, however, it is necessary to open a quarry by excavating in a fairly level surface, and then the rock must be hauled up an incline to the surface.

In almost every quarry the variations in the rock in different parts make it advisable to have an extensive face and tracks radiating to different points in order to obtain a mixture of uniform composition by combining the rock high in lime with that low in lime.

Formerly the rock was quarred in benches by the use of small drills and small blasts. Now, however, the companies have found it more economical to blow down enormous masses of rock at one time, at some blasts more than 60,000 tons. To do this a series of churn drill holes is put down about ten to fifteen feet back from the quarry face and about the same distance apart and driven to the level of the bottom of the quarry, which is usually about 100 feet. These holes are then charged with dynamite and exploded simultaneously by an electric detonator. The rock is so easily shattered that these great blasts break most of the rock sufficiently to be loaded into cars. The larger blocks are broken by small charges of dynamite placed in holes made by small compressed-air hand drills.

Steam shovels are used for loading the rock into cars. In the quarries that are driven into the hillsides on the level, small locomotives or mules are used to haul the cars to the mill. Where the quarry is sunk below the level of the mill the cars are pushed by hand or hauled by mules to the foot of the incline, where they are attached to a cable to be hauled up the slope. In recent years trucks have been largely substituted for cars to transport the stone from the quarry to the mill. The rock is dumped into a storage bin or directly into the gyratory crushers.

PORTLAND CEMENT MANUFACTURE

In general there is little variation in the methods employed throughout the region for the manufacture of portland cement, although somewhat different types of machinery are used. The different stages in a dry-process plant include (1) coarse grinding, (2) drying, (3) fine grinding, (4) calcining, (5) cooling or seasoning, (6) mixing with gypsum and grinding the clinker, and (7) seasoning in storage houses preparatory to bagging or packing in barrels. These processes have been described in many publications that deal with the technical side of cement manufacture.

The first kilns used in the district were upright. They consisted of three compartments, an upper heating chamber, a middle clinkering chamber, and a lower cooling chamber. The pulverized rock was mixed with water and molded into bricks, which were first dried and then carefully placed in the upper chamber by hand. The material passed in turn through the other chambers and was withdrawn at the base. These kilns were not satisfactory, for much of the material was not uniformly burned, the amount of labor required was excessive, and scarcely more than 100 barrels of cement could be burned in each kiln daily. On the other hand, the fuel consumption in the upright kilns, which ranged from 45 to 65 pounds of coal to the barrel of cement, was much less than that required in the rotary kilns.

From the mills the cement is taken to the storage bins, where it remains for some time to season and is then withdrawn for shipment. It is shipped in paper or occasionally cloth bags that hold 95 pounds. Originally much was shipped in barrels that held 380 pounds. The Bates valve bag is widely used in the district. Bulk shipment in freight cars of special construction started a few years ago and is increasing.

Descriptions of Individual Plants

Four different portland cement companies have 9 mills in Lehigh County. All are working the argillaceous limestone of the Jacksonburg formation. A general description of the physical and chemical characteristics of the stone used is equally applicable to all the quarries. In detail, there are some important differences in that the percentages of $CaCO_3$ and $MgCO_3$ may vary a few points and thus render the stone highly acceptable or otherwise. In general the Jacksonburg limestone of Lehigh County is deficient in $CaCO_3$, thus necessitating the purchase of high-calcium stone, most of which comes from the Lebanon Valley.

Cement Mills in Lehigh County

1. Coplay Cement Manufacturing Co.
   One mill at Coplay
2. Giant Portland Cement Co.
   Two mills near Egypt
3. Lehigh Portland Cement Co.
   Mills, A, D and F at Ormrod; B at West Coplay and H at Fogelsville
4. Whitehall Cement Manufacturing Co.
   One mill at Cementon

Besides these existing plants there was the initial plant of the Universal Atlas Cement Co. located between Cementon and Coplay, first known as the Keystone Co. and later as the Atlas Portland Cement Co. It is known as the Coplay plant of the Universal Atlas Cement Co. Operations were started in 1889. In 1895 the company built a plant on the east side of the Lehigh River in Northampton County and in 1907 abandoned its operations in Lehigh County, although still holding a lease on the property. The mill is now practically in ruins.

COPLAY CEMENT MANUFACTURING CO.

The oldest cement company in the Lehigh District as well as the oldest in the entire country is the Coplay Cement Manufacturing Company. Under the name of Coplay Cement Co. it was incorporated in 1866. A small plant was erected and shipments made the same year. This was the first portland cement produced in the United States. The first mill and quarry were located along the Lehigh Valley Railroad in the north part of Coplay. This company has taken part in all the major developments of cement manufacture. David O. Saylor was president of the company and in general charge.

The first mill erected has been designated as Mill A. It has been entirely scrapped. The kilns were of the old-fashioned upright dome type used for burning lime (pl. 31).

The process of manufacture used by Saylor was simple and primitive when compared with modern practice. The ingredients were ground with buhrstones, mixed with water, and molded into bricks, first by hand and later by brick-making machines. These were dried naturally or by steam pipes and then placed in upright bottle-shaped kilns from 30 to 40 feet in height and from 12 feet in diameter, where the greatest bulge occurred, to about four feet at the top. At the bottom of the kiln a layer of wood was placed and then alternate layers of coke and dried bricks of the cement ingredients. These had to be carefully placed in the kilns by hand. Openings in the kilns at different levels facilitated their filling and later these were closed by brick. When the kiln was filled, the wood at the base was ignited and the burning took place.

After the burning process was ended the resulting product was taken out at the base of the kiln. Portions that had been burned to partial fusion formed large or small masses of clinker which were broken into sizes easily handled and sent to the mill for grinding. Those portions insufficiently burned were again molded into bricks for re-burning. At times as much as 40 percent required further burning. For some time, the clinker was ground in a mill that was set up in an old distillery about half a mile away, but later a new mill was built near the quarry and kilns.

These intermittent kilns of small capacity and requiring a large amount of hand labor were used at the Coplay plant until about 1892 or 1893.

Up to the time of Mr. Saylor's death in 1884 the bottle-shaped intermittent kiln was the only type used in this country and the process of manufacture was expensive, notwithstanding cheap labor, because of the large number of men required. The best these kilns could do was to produce 150 to 200 barrels of cement every ten days.

Although Saylor had proved that good quality portland cement could be made from the cement rock of Lehigh and Northampton counties, and other mills shortly started in the same vicinity, still the business was not highly profitable. It was hard to convince the users of cement that the American manufacturers had succeeded in producing portland cement of the same quality as that imported from Europe. Naturally the importers did all they could to discredit the home product and the American portland cement gained recognition slowly.

The next development of the company was the construction in 1893 (or 1892) of Mill B, which was equipped with the upright continuous Schoefer (Schaffer) kilns, introduced from Germany. These kilns are still standing as shown in Pl. 31. The mill was modified and rebuilt several times. In this mill were installed the first rotary kilns of the district, an innovation frequently credited to the Keystone Portland Cement Co. (forerunner of the Atlas Cement Co.) whose property adjoined that of the Coplay. The first rotary kilns were 40 feet in length.

Part of Mill B still remains, although at present it is used only for storage and packing.

Mill C, located a short distance west of Mills A and B, is of modern construction. It has undergone numerous changes and is still in process of modification to permit the manufacture of the various kinds of cement now demanded, and to improve quality and reduce costs. The dry process is employed. It has an annual output of 2,400,000 barrels of "Saylor's Portland Cement." The mill is equipped with eight 125-foot kilns, of which five have a diameter of 7½ feet and the other three 9 feet.

The quarry which at first supplied the stone is close to the Lehigh Valley R. R. It has been discontinued and a new one opened about half a mile to the west. At present it covers about 10 acres and is 370 feet deep. The upper portion, about 195 feet, furnishes about 70 percent of the stone. It is too low in $CaCO_3$ for a mix, averaging about 73 percent, although containing some high-calcium-limestone lenses. The lower portion, 175 feet, furnishes about 30 percent of the stone requirements. Its stone averages from 86 to 88 per cent $CaCO_3$. The two kinds of stone represent the divisions of the Jacksonburg formation characterized by the writer as the "cement rock" and the "cement limestone."

The rock strata in part of the quarry are much folded, as well shown by a prominent overturned recumbent fold in the northeast part of the quarry. Other folds and some faults are present. At depth the strata are much more regular.

Owing to the complexities of structure, underground water circulates freely and readily enters the deep quarry. A minimum of 4,500 gallons per minute must be pumped to keep the quarry dry. At times this runs as high as 8,500 gallons.

The variation in chemical composition of the stone is shown in the analyses of the cuttings from a typical drill hole.

Variations in calcium carbonate content in a drill hole

Feet		Feet		Feet		Feet		Feet		Feet	
5	64.87	105	67.39	205	64.87	305	68.02	405	69.59	505	92.19
10	65.18	110	70.85	210	68.34	310	68.97	410	70.69	510	85.14
15	65.18	115	72.73	215	72.73	315	65.50	415	71.16	515	81.54
20	68.34	120	72.73	220	69.28	320	66.30	420	70.53	520	89.69
25	64.87	125	77.16	225	67.08	325	72.73	425	72.42	525	87.18
30	68.50	130	71.16	230	65.18	330	69.59	430	76.21	530	76.51
35	69.59	135	67.39	235	65.18	335	62.98	435	63.61	535	77.14
40	73.68	140	68.34	240	63.61	340	60.14	440	67.87	540	82.01
45	70.22	145	73.68	245	66.45	345	57.94	445	69.28	545	92.27
50	68.97	150	67.71	250	65.82	350	60.45	450	86.71	550	84.09
Avge.	67.94	Avge.	70.91	Avge.	66.85	Avge.	65.25	Avge.	71.81	Avge.	84.78
55	68.34	155	65.50	255	70.07	355	65.82	455	74.63	555	84.88
60	68.65	160	68.97	260	69.75	360	67.08	460	79.34	560	90.86
65	69.59	165	69.59	265	69.59	365	72.73	465	76.82		
70	67.08	170	64.40	270	68.34	370	74.94	470	62.40	Composite of 560 Feet	
75	71.16	175	67.08	275	66.77	375	66.77	475	79.34		
80	68.34	180	64.87	280	71.79	380	71.16	480	88.44	SiO_2 ---	15.70
85	68.34	185	65.50	285	65.03	385	69.91	485	91.25		
90	71.16	190	65.03	290	65.03	390	67.71	490	90.31	Fe_2O_3 Al_2O_3	6.84
95	70.53	195	68.50	295	66.14	395	69.59	495	93.45		
100	70.22	200	68.97	300	66.45	400	69.59	500	90.93	$CaCO_3$ -	71.84
Avge.	69.34	Avge.	66.84	Avge.	67.89	Avge.	69.53	Avge.	82.69	$MgCO_3$ -	5.50

The years of operation and total production are included in the table on a later page.

UNIVERSAL ATLAS CEMENT CO.

The first plant of the Universal Atlas Cement Co. was located in Lehigh County immediately north of the first operations of the Coplay Cement Manufacturing Co. The company was first named the Keystone Portland Cement Co. In 1890 it was changed to the Atlas Cement Co. and much later to the present name. The quarry and mill were small. Here it is claimed were installed the first rotary kilns in the Lehigh District. The hillside quarry had a face about 100 feet high.

The first production was in 1889. The mill was closed in 1907, although kept in order for many years thereafter to fulfill the terms of an unusual lease. There is little prospect of the plant ever being operated again, as the property is too restricted for such operations as are now economical.

HERCULES CEMENT CO.

A cement company that has passed out of existence was located directly north of the Atlas property along the Lehigh Valley Railroad.

The original developments on this site date back to 1872 when a company was organized under the name of the Lehigh Hydraulic Cement Works. "It consisted of three run of millstone, and ample power to grind three hundred barrels of cement a day. The kilns are four in number, and of the No. 12 pattern, described in Gen. Q. A. Gilmore's work on cement. The quarry is adjacent to the works, and the cement made was a light yellow one, closely resembling in color and quality that made by the Old Lehigh and Allen Works" (Prime, 1878). The mill burned down in 1874.

The Lehigh Valley Portland Cement Co. organized in 1880 and erected two kilns and a mill. It operated for about a year. Reorganized about 1884 under the name of the Hercules Cement Co. and equipped to produce both natural and portland cement, production from this small operation seems to have been resumed in 1885. A bad fire about 1897 closed the plant and it was not rebuilt. The property now belongs to the Whitehall Cement Manufacturing Co. According to best available information it seems that rotary kilns never were installed. No production figures have been obtained.

GIANT PORTLAND CEMENT CO.

The holdings of the Giant Portland Cement Co., the second company in the county to make portland cement, are south and southwest of Egypt. The parent concern was organized for the manufacture of natural cement only. Later both natural and portland cement were manufactured; eventually the sole production was portland cement.

The original plant was known as Egypt Mills, located immediately southeast of Egypt, where a large quarry was worked and a line of natural cement kilns erected. The first cement was made in 1884. Portland cement was never made here, but natural cement was produced long after the company began the manufacture of portland cement at other points.

In 1884 the American Improved Cements Co. was organized. It later took over the Egypt Mills plant. This company was succeeded by the Pennsylvania Cement Company, organized in 1889, which acquired all the property and assets of the American Improved Cements Co. A new mill, known as the Pennsylvania Mill, was built close to the crossing of Coplay Creek by the Ironton Railroad. In 1890 or 1891 the name was changed to the American Cement Company of Pennsylvania. This was the operating unit and a subsidiary company of the American Cement Company of New Jersey.

Several more mills were built. The first was the Columbia, located between the railroad and Coplay Creek about two-thirds of a mile south of Egypt. This was followed by Giant Mills Nos. 1 and 2, a short distance north of the Pennsylvania Mill.

So far as determined, the first portland cement was made in Giant Mill No. 2, although it is possible that some was produced in one or more of the earlier mills.

In 1903 the Central Mill was erected almost directly west of the old Columbia Mill. This was a much larger mill than the preceding ones and the adjacent quarry is of large size. It is now idle, but can be put into operation if needed.

In 1905 the Reliance Mill, at present the only operating unit, was built about half a mile southwest of Egypt. Some of the buildings of the other mills are still intact and used for storage.

In 1911 the American Cement Company of New Jersey and its subsidiary, the American Cement Company of Pennsylvania, went into receivership, but continued to operate on a reduced scale. A reorganization was effected in March 1913 under the name of the Giant Portland Cement Co. At present the company has 14 kilns, six of which are 7½ feet in diameter and 125 feet long and eight that are 6 feet in diameter and 60 feet long. The dry process is in use and the annual capacity is 2,100,000 barrels. Types 1 and 2 of the recently established five types of cement are made but several varieties of each type are produced.

The sidehill quarry at mill level covers about 26 acres. The height of the quarry face ranges from 75 to 125 feet.

An average analysis of the quarry stone is as follows:

SiO_2 15.60, Fe_2O_3 1.50, Al_2O_3 6.00, $CaCO_3$ 72.70, $MgCO_3$ 4.48, SiO_2 ratio 2.01.

For a while the company worked a property known as the Lobach quarry south of Ormrod to obtain high-grade limestone. Underground mining was not successful, largely on account of the badly folded and faulted strata and the presence of interbedded dolomitic beds.

LEHIGH PORTLAND CEMENT CO.

The Lehigh Portland Cement Co. was organized in 1897. It has developed into one of the largest cement companies in the United States with plants in Lehigh, Northampton, and Lawrence counties, Pennsylvania, and in New York, Maryland, Virginia, Alabama, Indiana, Illinois, Iowa, Kansas and Washington. Five plants have been built in Lehigh County, of which three are located at Ormrod and the other two at West Coplay and Fogelsville.

The Ormrod A plant began operations in Aug. 1898 and continued until Sept. 1927. It was abandoned in 1930. West Coplay started in

Jan. 1901, was operated until Aug. 1928 and abandoned in 1933. The second mill at Ormrod, Ormrod D, began production in July 1902 and is still in operation. Ormrod F began operations in Oct. 1903 and continued to Nov. 1936. The Fogelsville plant (pl. 32) has produced from Mar. 1907 to the present. With the exception of Ormrod A, which at its maximum in 1926 produced slightly more than 750,000 barrels, each of the plants has produced considerably over a million barrels in certain years.

The plants of the company have kept pace with the developments in the cement industry and have undergone many changes. Different types of cement are produced. The Fogelsville mill is equipped with 10 rotary kilns 5½ to 7½ feet in diameter and 125 feet in length with an annual capacity of 2,005,675 barrels. The Ormrod D mill likewise has 10 kilns of the same diameter, but only 92 feet in length. This mill has an annual capacity of 1,603,810 barrels.

Several different quarries have been operated from time to time. At Ormrod the active quarries have an area of 35 acres and the inactive 27 acres; at Fogelsville 30 acres of active and 2 acres of inactive; and at West Coplay 21 acres of inactive quarries.

The extreme height of the present Ormrod quarry is 185 feet and of the Fogelsville quarry 180 feet. In both quarries there are many complex folds and minor faults. These complications have brought the Beekmantown limestone on top of the Jacksonburg at Ormrod. In the vicinity there are a number of other instances of overturned folds. In part of the Ormrod quarry there are abundant veins of calcite occasionally mixed with quartz. These white veins in the black cement rock present a striking appearance.

Analysis of stone, Fogelsville quarry

Northwest face

Feet	$CaCO_3$	$MgCO_3$
0-25	clay	
25-30	76.8	2.5
30-40	73.1	2.5
40-50	79.5	3.1
50-60	74.9	2.8
60-70	74.3	3.0
70-80	75.3	3.0
80-90	73.9	4.0
90-100	72.7	4.0
100-110	71.2	3.5

Composite analysis

SiO_2	13.95
Al_2O_3	4.27
Fe_2O_3	1.48
$CaCO_3$	74.75
$MgCO_3$	2.43

East face

Feet	$CaCO_3$	$MgCO_3$
0-10	clay	
10-20	63.6	2.1
20-30	63.9	2.0
30-37	67.2	3.0
37-39½	59.9	14.5
39½-50	70.9	3.0
50-60	65.3	2.5
60-70	62.3	2.5
70-80	65.2	3.0
80-90	65.6	2.5
90-96	69.3	2.7
96-105	80.8	4.0
105-115	85.2	4.0
115-125	84.6	5.0
125-135	83.5	5.5
135-140	69.7	18.6

Analysis of stone, Ormrod quarry

Feet	$CaCO_3$	Feet	$CaCO_3$	Feet	$CaCO_3$
0-10	66.4	50-60	69.7	100-110	64.1
10-20	69.1	60-70	69.7	110-120	83.7
20-30	68.2	70-80	65.6	120-130	81.9
30-40	69.4	80-90	60.4	130-140	50.8
40-50	68.8	90-100	64.5		

WHITEHALL CEMENT MANUFACTURING CO.

The forerunner of the Whitehall Company was the United States Cement Co., which was sold to the organizers of the present company. The Whitehall plant is in Cementon. The first production was made in 1900. The plant was shut down in 1909, but the company reorganized and resumed production in 1911.

The quarry driven westward into the hill at road level covers about 50 acres and has a face 172 feet high. The mill is equipped with five kilns 120 feet in length and 8½ and 10 feet in diameter. The annual output is 2,200,000 barrels. At present cement of types 1, 2 and 3 are being made.

The stone in the quarry shows considerable variation. The analyses of stone encountered in prospect hole No. 23 are fairly typical.

Analysis of stone, Whitehall Cement Mfg. Co. hole No. 23

Feet	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$
8— 32	9.56	3.48	1.28	81.50	3.35
32— 62	10.60	3.62	1.66	80.23	3.67
62— 91	10.82	3.90	1.66	78.42	3.79
91—121	15.30	5.40	1.92	71.72	3.73
121—150	11.48	4.23	1.57	78.47	4.24
150—180	16.46	5.23	2.05	71.08	4.23
180—210	29.06	7.80	3.08	53.22	4.71
210—235	17.28	6.93	2.29	66.39	4.30

Production of Portland Cement in Lehigh County

Years	Coplay	Giant	Atlas (Coplay plant)	Hercules	Lehigh					Whitehall	Barrels	Price per bbl.	Total value
					Ormrod A	West Coplay	Ormrod D	Ormrod F	Fogelsville				
1866 to 1884	*										370,000†	$3.00‡	$1,110,000.00
1885	*			*							600,000†	1.89‡	1,134,000.00
1886	*			*									
1887	*			*									
1888	*			*									
1889	*		*	*									
1890	*		*	*							201,000	2.09‡	420,090.00a
1891	*		*	*							248,500	2.13‡	529,305.00a
1892	*		*	*							280,840	2.11‡	592,572.40
1893	*		*	*							265,317	1.96‡	520,021.32
1894	*		*	*							485,329	1.73‡	839,619.17
1895	*	*(?)	*	*							634,276	1.60‡	1,014,841.60
1896	*	*	*	*							941,668	1,57‡	1,478,418.76
1897	*	*	*	*							1,283,092	1.61‡	2,065,778.12
1898	*	*	*								1,624,516	1.62‡	2,631,715.92
1899	*	*	*								2,080,942	1.43‡	2,975,747.06
1900	*	*	*		*						2,775,979	1.09‡	3,025,817.11a
1901	*	*	*		*	*				*	3,577,939	.99‡	3,542,159.61
1902	*	*	*		*	*	*			*	4,485,252	1.21‡	5,427,154.92
1903	*	*	*		*	*	*	*		*	5,472,446	1.24‡	6,785,833.04
1904	*	*			*	*	*	*		*	6,294,160	.88‡	5,538,860.80
1905	*	*			*	*	*	*		*	6,948,833	.96‡	6,670,879.68
1906	*	*	*		*	*	*	*		*	8,000,000+	1.13‡	9,040,000.00
1907	*	*	*		*	*	*	*	*	*	8,370,527	1.11‡	9,291,284.97
1908	*	*			*		*	*	*	*	6,920,827	.75	5,190,620.25
1909	*	*			*	*	*	*	*	*	7,797,985	.69½	5,419,599.57
1910	*	*			*	*	*	*	*		7,289,459	.72	5,247,410.48
1911	*	*			*	*	*	*	*	*	7,314,571	.72	5,266,491.12
1912	*	*			*	*	*	*	*	*	6,736,252	.67	4,513,288.84
1913	*	*			*	*	*	*	*	*	9,467,813	.84	7,952,962.92
1914	*	*			*	*	*	*	*	*	7,063,112	.81	5,721,120.72
1915	*	*			*	*	*	*	*	*	8,057,490	.70	5,640,243.00
1916	*	*			*	*	*	*	*	*	6,790,140	.94	6,382,731.60
1917	*	*			*	*	*	*	*	*	7,069,044	1.22	8,624,233.68
1918	*	*			*	*	*	*	*	*	5,781,676	1.52	8,788,147.52
1919	*	*			*	*	*	*	*	*	6,223,757	1,64	10,206,779.48
1920	*	*			*	*	*	*	*	*	7,074,139	1.93	13,653,088.27
1921	*	*			*	*	*	*	*	*	6,894,324	1.78	12,271,896.72
1922	*	*			*	*	*	*	*	*	8,684,648	1.63	14,155,976.24
1923	*	*			*	*	*	*	*	*	10,306,573	1.81	18,654,897.13
1924	*	*			*	*	*	*	*	*	10,643,520	1.72	18,306,854.40
1925	*	*			*	*	*	*	*	*	11,054,389	1.74	19,234,635.86
1926	*	*			*	*	*	*	*	*	11,744,940	1.71	20,083,847.40
1927	*	*			*	*	*	*	*	*	10,841,987	1.55	16,805,079.85
1928	*	*				*	*	*	*	*	9,308,017	1.52	14,148,185.84
1929	*	*					*	*	*	*	8,869,865	1.41	12,506,509.65
1930	*	*					*	*	*	*	7,574,700	1.39	10,528,833.00
1931	*	*					*	*	*	*	6,758,605	1.09	7,366,879.45
1932	*	*					*	*	*	*	3,547,595	.99	3,512,119.05
1933	*	*					*	*	*	*	2,649,959	1.27	3,365,447.93
1934	*	*					*	*	*	*	2,896,196	1.50	4,344,294.00
1935	*	*					*	*	*	*	3,021,824	1.46	4,411,863.04
1936	*	*					*	*	*	*	4,433,148	1.38	6,117,744.24
1937	*	*					*		*	*	4,886,750	1.51	7,378,992.50
1938	*	*					*		*	*	4,190,086	1.32	5,530,913.52
1939	*	*					*		*	*	5,757,341	1.38	7,945,130.58
1940	*	*					*		*	*	5,938,029	1.39	8,253,860.31
Total											288,529,377	$1.29ǂ	$372,164,777.64

* Production during year.

† Estimated production.

‡ Average price per barrel in country; other prices per barrel are value in Lehigh District.

ǂ Average.

a Figures for 1890 include some New Jersey production; for 1891-99 may include New Jersey production; for 1900-06 include minor amounts of Northampton County production.

BUILDING STONE

Although stone has been quarried in many places in Lehigh County, no important building stone industry has ever been developed, other than the roofing slate industry which is discussed elsewhere. Locally, the Cambro-Ordovician limestones, the Hardyston sandstones and quartzites, the Tuscarora sandstones and conglomerates, and the pre-Cambrian gneisses have all been used but only in small quantities. Waste slate blocks have been used for the construction of small buildings near some of the slate quarries. After exposure to weathering these buildings present a bizarre appearance as the bands or ribbons become objectionably prominent.

Limestone.—Lehigh County contains some attractive stone houses mainly built before 1850. Since then limestones have been quarried rarely for building purposes. The limestones that have been used in residences and barns have come mainly from local quarries that have also been worked for lime and crushed stone.

The principal reason for the limited use of limestones for building is the expense of dressing the stone. The great compression that all of the limestone strata of the region have suffered, developed several systems of joint fractures along which the stone breaks. Rectangular blocks can seldom be obtained by the ordinary quarry methods. Both thin and massive beds yield angular blocks of all shapes and sizes. Masonry construction under these conditions is unduly expensive.

Also, the shallow-water origin of the limestones resulted in rough surfaces, interbedded shaly laminæ and beds of varying thickness. Veins of quartz and calcite are numerous where the rocks were shattered by folding and faulting. In places secondary flint nodules are abundant.

The limestone has been used in irregular blocks, called "rubble construction;" in rectangular blocks of fairly uniform thickness, designated "coursed ashlar;" and in rectangular blocks of varying thickness known as "random or broken ashlar." Most of the old stone houses have walls several feet thick, with rough-shaped blocks in mortar inside the more neatly built external walls. In some cases the masonry of the outer walls is of poor construction and the exterior has been covered with plaster.

To satisfy the small continuing local demand for limestone for buildings and walls, some quarries now operated for crushed stone will set aside the occasional desirable well-shaped blocks that may be shot down in blasting. In this way some fine building stone has been obtained at reasonable expense. It is probable that local limestones will long be used in small amounts for construction of buildings, bridges and walls, but the quarrying of such material is apt to be incidental to other purposes.

Sandstone and quartzite.—The Hardyston formation contains siliceous beds that are commonly known as quartzites, although generally the degree of metamorphism is so slight that they are more appropriately called sandstones. They rest unconformably on the gneisses and now crop out mainly on the slopes of the gneiss hills but in a few cases extend to the summits. This is the most attractive building stone in the county and the one most generally used at the present time.

These sandstones have been quarried in several places in Lehigh County and in the adjoining counties of Berks and Northampton. They were long known to the building trade as the Potsdam sandstone under the mistaken idea that they were of the same age as the Potsdam formation of New York State.

Nearly all the sandstone quarries (Plate 44) of Lehigh County are on the north slope of the spur of South Mountain that extends from Fountain Hill to South Allentown. The Hardyston strata dip northward toward the Lehigh River. In places they dip at about the same angle as the slope of the mountain but generally the dip is greater so that individual beds crop out on the mountainside. A short distance northwest of Fountain Hill a quarry was opened near the summit of the mountain but in most places erosion has removed the Hardyston strata from the upper slopes. The quarries are small because the combined thickness of workable beds is seldom over 20 feet. Several quarries have been worked east of the Bethlehem municipal pumping station. Another quarry with westerly dipping beds has been opened on the west end of this mountain. Similar rock has been quarried on the mountain slope southeast of Emmaus and in small amounts in several other localities.

Local differences are so minor that it is not necessary to describe the individual quarries. The rock is a hard, compact stone composed of quartz sand grains with some quartz pebbles as much as one-fourth inch in diameter. A basal layer with pebbles up to two inches in diameter and with a dark-colored matrix is generally present but not used. When fresh, the rock is gray to bluish-white but a band of discoloration from one-eighth to one inch in depth has stained the stone to a ferruginous brown or red along bedding planes and joint cracks. This is due to the presence of numerous tiny cubes of pyrite that are almost invariably present in the unaltered stone. They may be seen with the naked eye but better with a hand lens. At one time builders sought the gray fresh stone but in recent years architects have expressed a decided preference for the discolored stone. The alteration has not weakened the stone to any appreciable extent. The beds vary in thickness from two to ten inches. The surfaces are fairly smooth and the joints regular, so that rectangular blocks of suitable size can readily be obtained. They are dressed easily.

Quarrying operations are not continuous as little of the product has been shipped and the local demand is only occasional. Nearly all the buildings on the Lehigh University campus have been constructed with this Hardyston sandstone. Moravian College has also used the stone and it is found in other public buildings in Bethlehem and Allentown. It is well suited for boundary and foundation walls and has been extensively used.

In the operation of the Hardyston sandstone quarries seldom have any quarry tools been used other than of the simplest kind. The crowbar and sledge are usually sufficient, although some hand drilling and blasting have been done in a few localities.

The Tuscarora sandstones and conglomerates of Kittatinny (Blue) Mountain contain some stone suitable for building purposes but they have been little used. So far as known, no stone of this kind has ever been quarried in Lehigh County. Some of the blocks from the talus slopes have been used but only in small quantities. The finest structure in the county built with this stone is Jacobs Church, Jacksonville, Lynn Township. The red variety, long known as the Red Medina sandstone, was used. It was built in 1926. The stone as loose blocks was obtained from the mountainside about 1 mile to the northwest. "The structure is random rock-faced ashlar, and the abundant pink, red, gray and light tan colors give a warm and cheerful aspect to the beautifully designed church." (Stone 1933)

This source of building stone is worthy of more consideration than it has received up to the present time. There is an abundance of stone in the mountain, it is extremely durable, and possesses attractive qualities. In general the beds are massive so that considerable equipment would be necessary for the operation of a quarry.

Within the Martinsburg formation, which is so abundantly represented in the northern part of the county, there are calcareous sandstones that have been used locally for foundations, walls, and ocasional small structures. The stone is gray when fresh but becomes ferruginous brown on exposure. This change is due to the oxidation of the fairly abundant small grains of pyrite in the fresh rock. Although dark in color it is nevertheless attractive in appearance.

Gneisses.—Elsewhere in Pennsylvania the pre-Cambrian metamorphic gneisses have been quarried extensively for structural stone but in Lehigh County they have been used sparingly. This is mainly due to the fact that the expense of quarrying is high on account of the toughness of the rock. The initial expenditure involved in opening a quarry is also great on account of the decomposition of the exposed rock. On the surface the gneisses of all kinds are so broken by the action of frost or so greatly decomposed that much waste rock must be removed to reach good stone. Below the zone of freezing the stone is broken by joints into large irregular blocks that could be handled economically only by expensive mechanical equipment. The irregularity of the joints would cause an excessively large amount of rock to be discarded as waste, although this condition may not prevail everywhere. As large quantities of crushed rock for concrete and ballast are required in the industries of the region and in making permanent roads, market might be found for the rock that is unsuited for building stone.

The gneisses of the county furnish a wide variety of stones, ranging from dark-brown hornblendic to light granitic rocks, some of which are beautifully banded and others present a uniform appearance.

The gneisses contain no objectionable minerals, except in a few localities where pyrite is a common constituent. The chemical and physical character of the rocks make them very durable as building stones under all climatic conditions.

A few attractive residences, churches, and barns in the county have been built of the local gneisses. In almost all of them, only loose field stones were used and no quarries opened. The stone has been dressed for rubble construction.

There is little doubt but that high-grade building stone might be got in various places in the gneiss hills of Lehigh County if the demand and market prices should warrant the expenditure of the rather large sum necessary for development and equipment.

At Seisholtzville, Berks County, less than two miles from the Lehigh County line, a granite quarry has been operated for twenty years. Some fine churches and office buildings in Allentown and Bethlehem and other cities are built of this stone.

Glacial boulders.—A very limited use has been made of glacial and river cobbles such as are common in the deposits of the Lehigh River and in the glacial moraines and kames of the county. Ordinarily these cobbles have been utilized only for lining gutters.

CLAY AND SHALE

Four different kinds of argillaceous materials have been used in Lehigh County for the manufacture of brick and tile. These are the residual limestone clays, the clays associated with the limonite iron ores, white clays in the Hardyston formation, and the Martinsburg shales.

Pottery and firebrick have been made but apparently mainly, if not entirely, from clays brought from New Jersey or elsewhere. At the present time no brick is being manufactured in Lehigh County.

Residual limestone clay

Throughout the limestone regions of Lehigh County there is a surface cover of residual clay composed of insoluble material derived from a great thickness of limestone which has been removed by solution. In portions of the area several thousand feet of limestone has been carried away. The amount of insoluble matter in these calcareous sediments varies but an average of 10 percent may be assumed as a fair figure. If all the residue still remained, we should have a surficial clay deposit about 300 feet deep. However, this is not the case. Seldom is the residual clay more than 20 feet deep, although in places it exceeds 100 feet; probably there is an average depth of only 5 to 10 feet. This means that most of the insoluble matter has been carried to the streams by surface erosion and transported beyond the confines of the county. Along the steeper valley slopes the limestones generally are exposed and the clay cover is present only over the flat divides.

The Illinoian Ice Sheet coming from the northeast extended through the limestone valley to a point midway between Wescosville and Trexlertown, and there is some evidence that a still earlier ice invasion may have gone still farther west. The ice removed much of the surface clay, and mixed clays, sands, cobbles and boulders from the regions to the northeast with that which remained. Therefore, the surficial clays of the county are in part residual clays formed *in situ* but with enough modification in certain places to justify their classification as glacial clays. The clay material, however, is of residual origin.

The upper one to three feet of these clays has been modified by the addition of vegetable humus so that it cannot well be used for brick. However, in some brickyards the top soil was not removed and discarded even though it was recognized that the mixture of soil and clay affected the quality of the brick. The clay rests upon an irregular limestone surface characteristic of limestone weathering. Knobs or pinnacles of limestone may rise almost or quite to the surface in clay pits averaging ten or more feet in depth. This situation has made the use of power shovels difficult or impossible in the operation of some pits. Steam shovels have been used in some places. Of course, most of the clay pits of an earlier day were worked exclusively by hand.

In the early settlement of the region small brick yards were opened near the principal villages. In the absence of railroads, canals, and good roads the product was seldom transported any considerable distance. As transportation facilities improved, most of the small plants were closed and brick were obtained from larger operations within the county or in adjoining regions.

Now there is little indication of the former manufacture of brick in several places where, according to historical records, clay pits and brick kilns were formerly operated.

In the History of Lehigh County (1914) is the following account of early brick making at Guthsville.

> Aaron Guth started the manufacture of building brick in the village before 1854. He erected a large kiln near the south bank of the Jordan, west of the road, and carried on the business until the race track was constructed in 1861. His production was many thousand and all were used in the erection of the brick buildings at Guthsville, including the hotel and store, and the Stettler, Snyder, Haas, Ritter, Diehl, Shuler and Hoffman dwelling-houses. Cord-wood was consumed for burning the brick. (p. 896.)

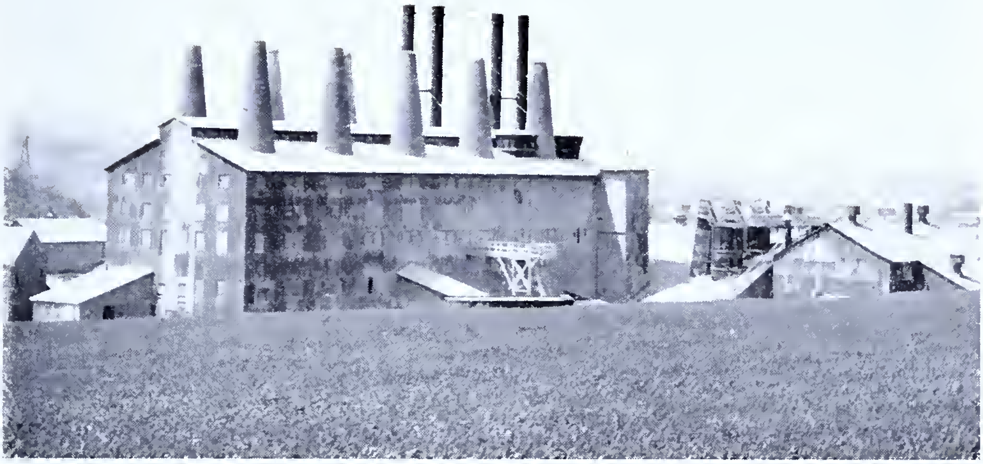
Most of the clay for brick has been dug in the suburbs of Allentown. Some of the pits were operated even after the city had grown and extended to or beyond the brick yards. Nine brick plants have been located in the north, east and south portions of the city. It is probable that clay was dug from still other localities where all evidence has been destroyed.

In 1886 according to a publication issued by the Board of Trade entitled "Past, Present and Future of the City of Allentown, Pa.", the following brick plants were in operation.

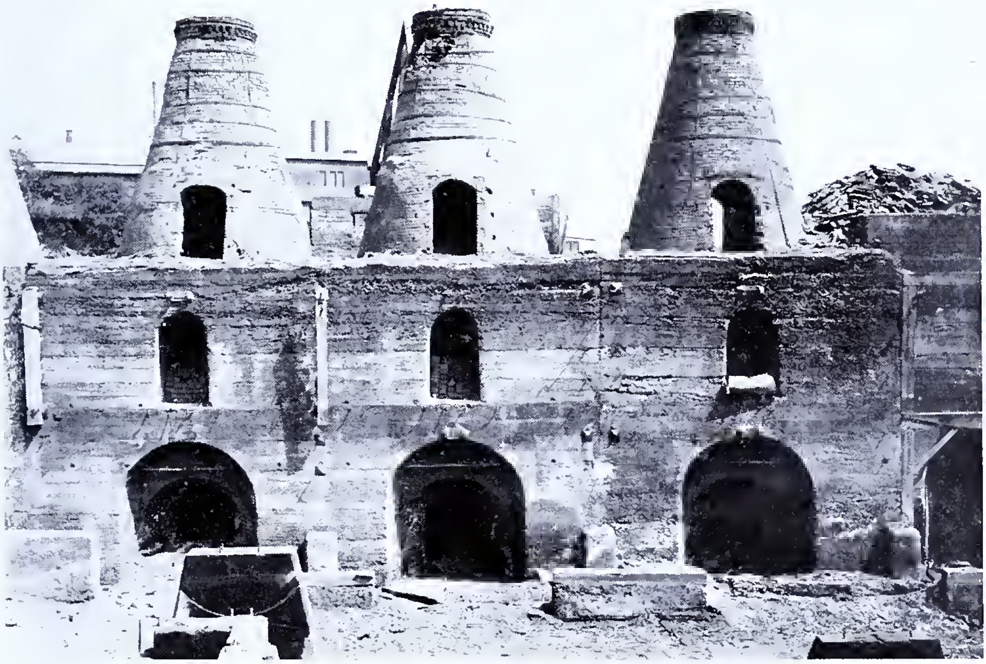
Daniel Swoyer had a plant on Ninth St. between Allen and Tilghman streets which he started in 1862. He had two kilns and produced 12,000 bricks daily.

W. J. Egge & Co. operated a brick plant on Tenth St. near Liberty. There were two kilns and six acres of clay land. The daily capacity was 18,000 bricks. It was started in 1861.

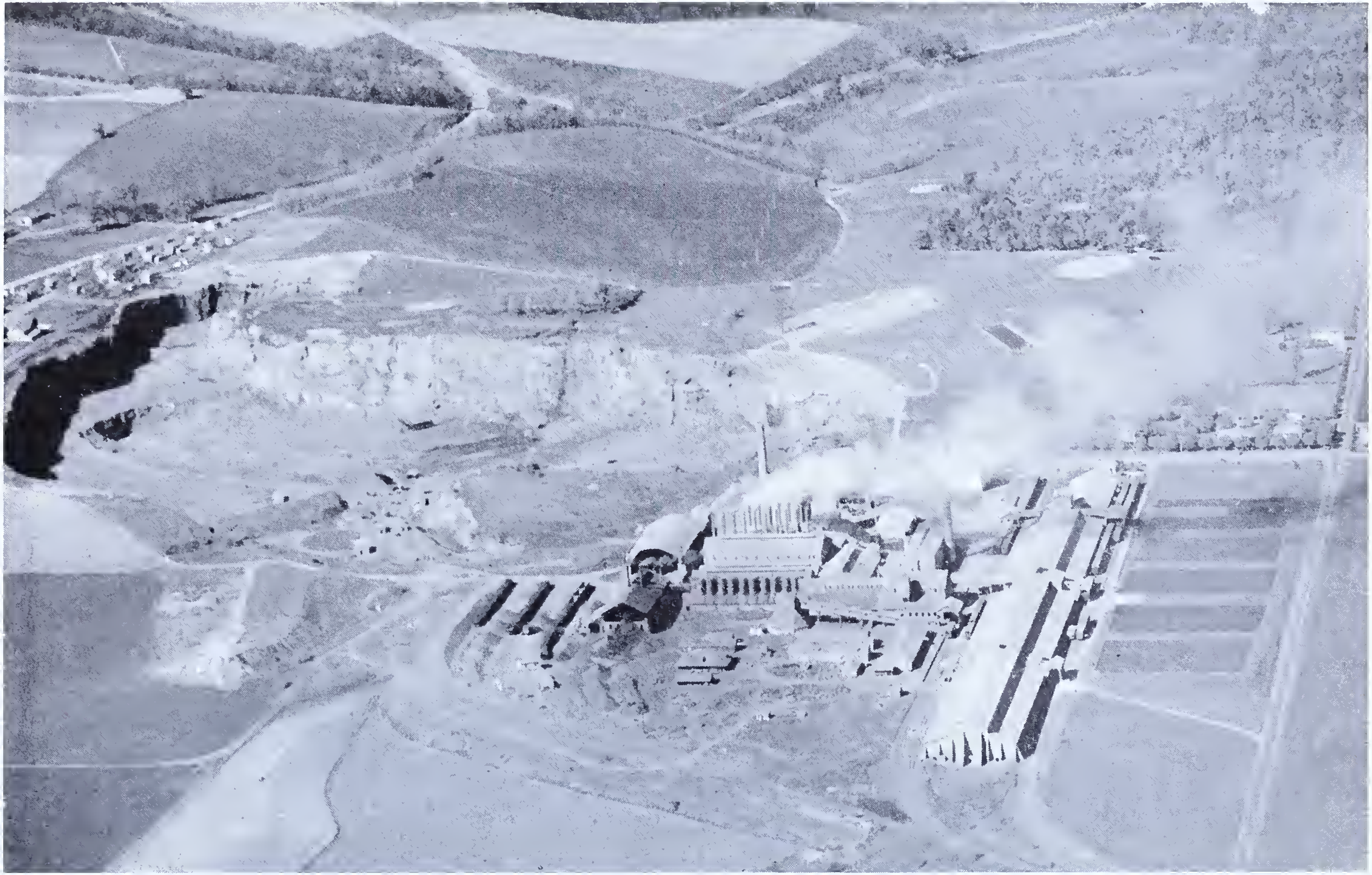
Edward Kiehline had a plant in South Allentown. "After you cross the old-fashioned bridge over the Little Lehigh at the foot of Lehigh Street, you pursue the winding road up past the toll-gate and then the ranges of shedding covering piles of brick, the two great



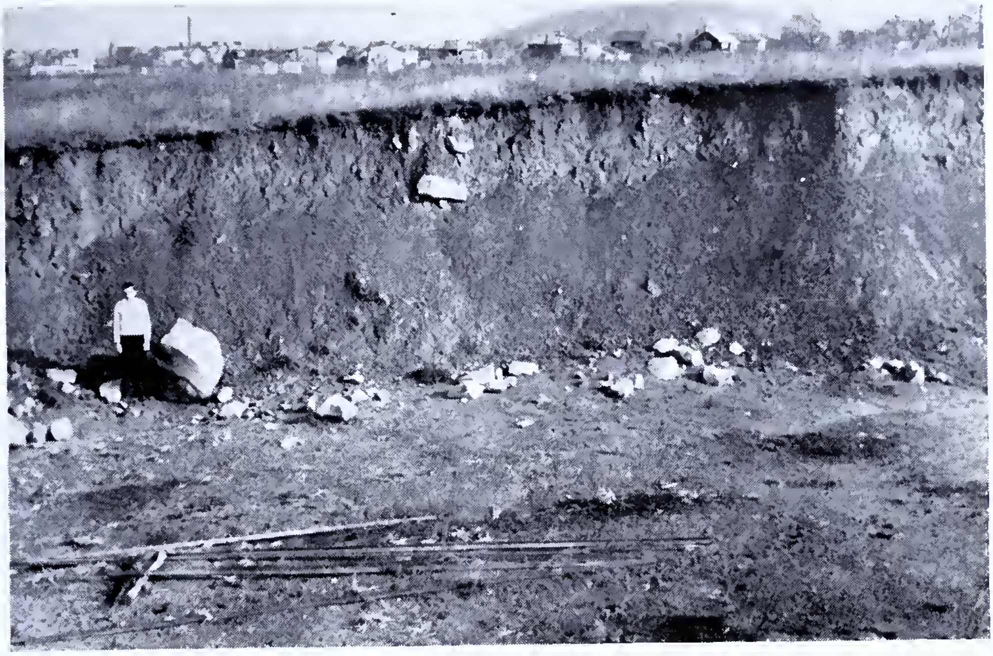
A. Old mill of the Coplay Cement Manufacturing Co., equipped with upright Schoeffer kilns.



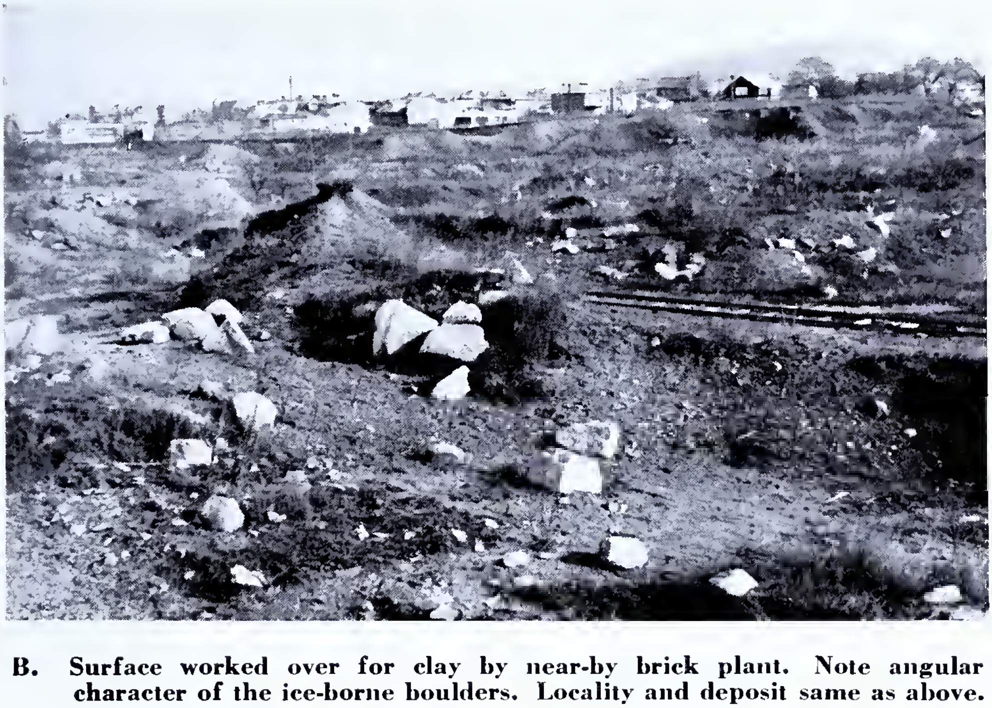
B. Close view of upright kilns of the Coplay Cement Manufacturing Co.
The pulverized stone was molded into bricks and placed in kiln much as kilns are filled in the manufacture of brick. The bricks were put in at two different levels. When the kiln was filled these entrances were blocked up.



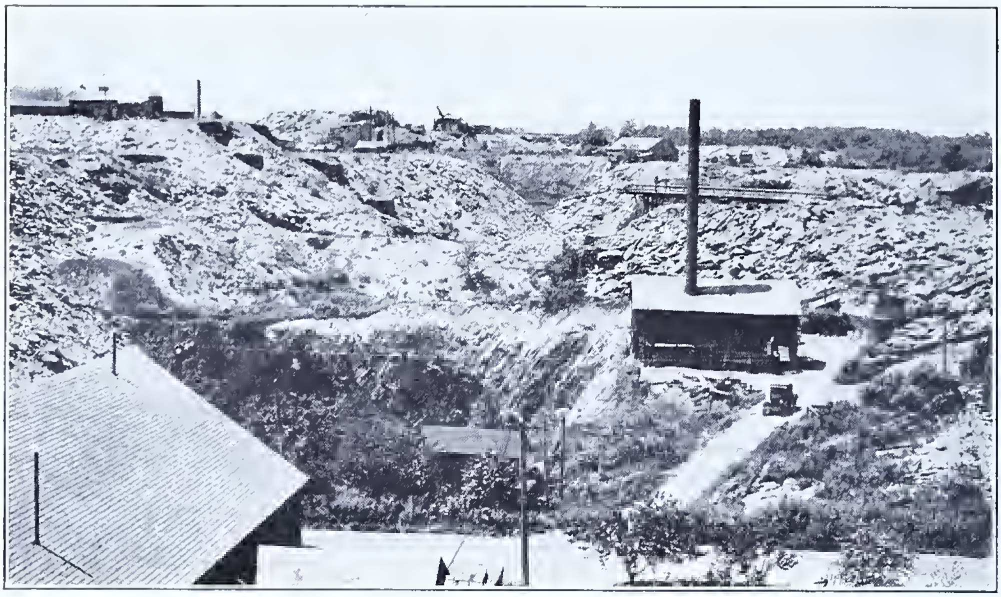
Fogelsville plant of the Lehigh Portland Cement Co. The billowy topography in the background is typical of erosional forms in areas underlain by Martinsburg shales.



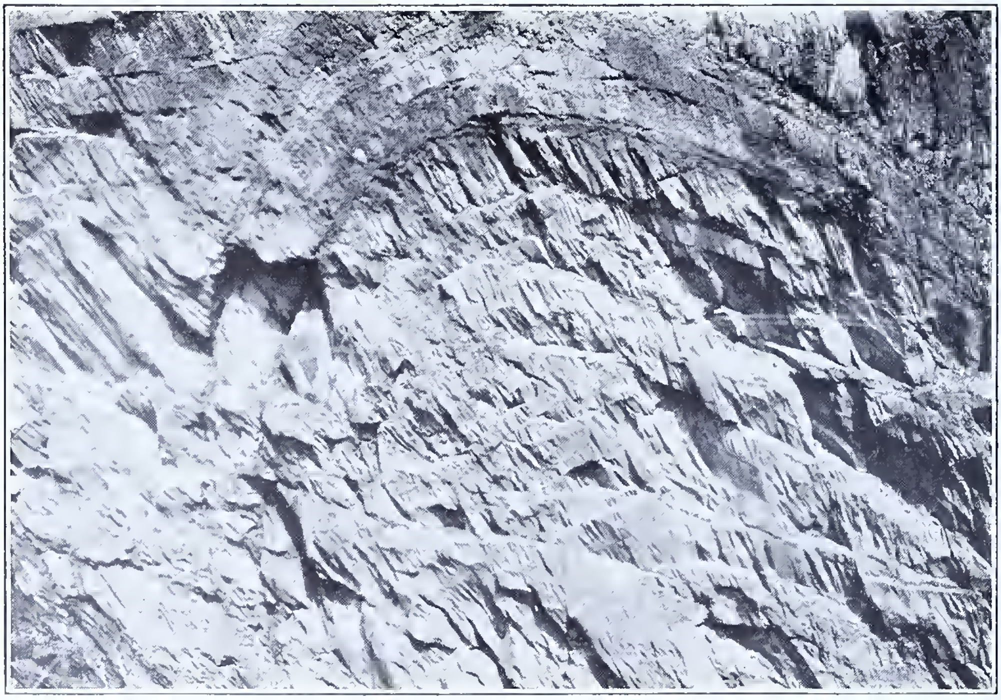
A. Illinoian glacial till in clay pit, South Allentown. Many of the boulders can be identified as derived from the Hardyston, Shawangunk, and Oriskany formations.



B. Surface worked over for clay by near-by brick plant. Note angular character of the ice-borne boulders. Locality and deposit same as above.

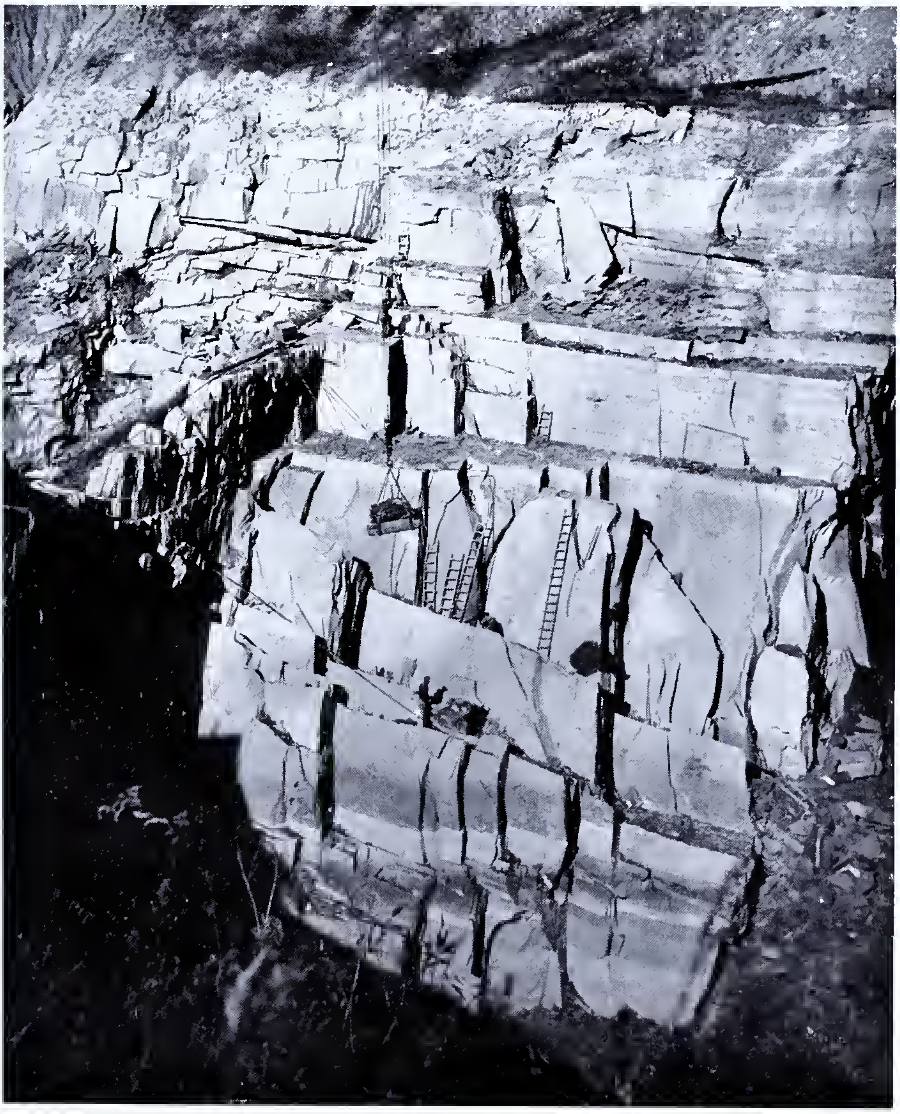


A. View southwest from Kern quarries at Slatedale.



B. Anticline of Eureka quarry, from middle of south side.

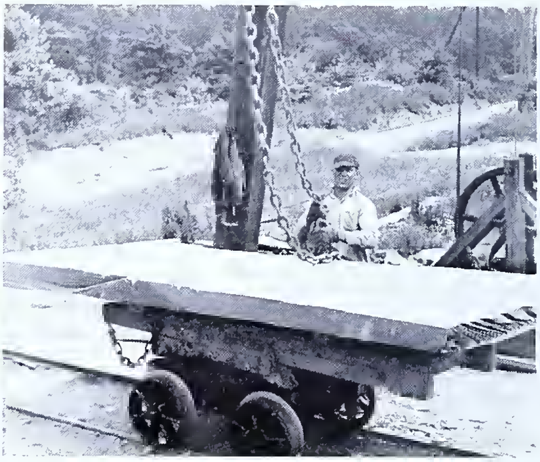
A. West part of Slatington with slate quarries near-by and Kittatinny Mountain beyond.



B. View in a typical slate quarry.

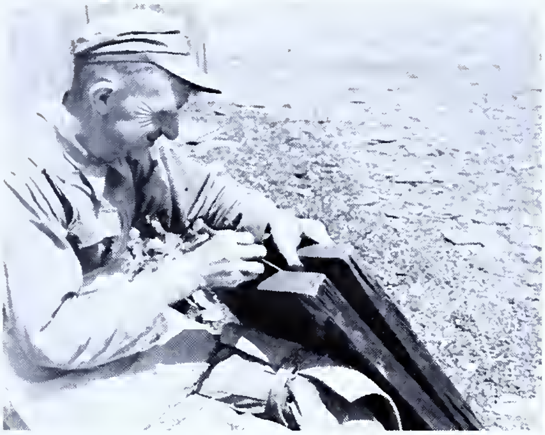
In this quarry the beds dip about 45 degrees. The large slabs are taken out between splits, which are the benches shown.

A. Quarrymen pry a slab loose.

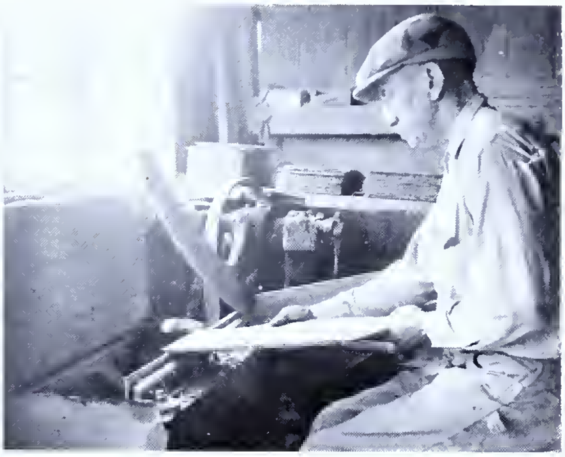


B. Hoisted to the surface, the slab is loaded on a small truck and trammed to the saw table.

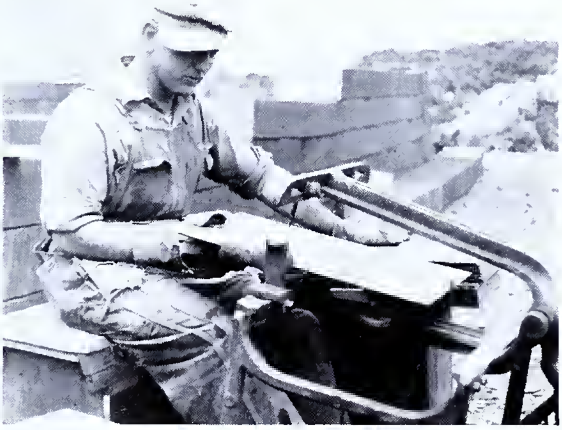
C. In the factory the slab is cut by a circular saw.



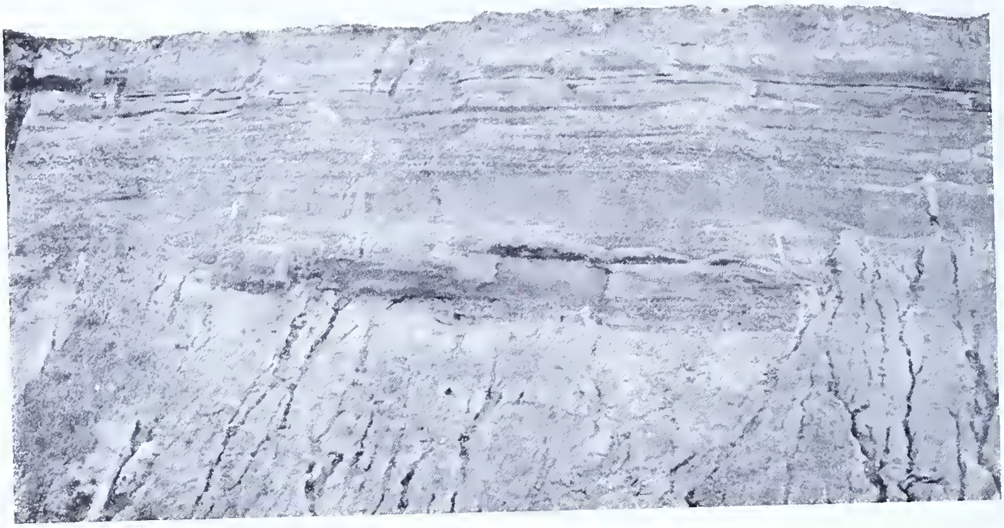
A. Splitting the slate. Each piece is split in half until the required thinness is obtained.



B. Trimming the slate. A steel blade operated by foot shears shingles to size.



C. Punching nail holes. On order specifying the overlap, two holes are punched in the shingles.



A. Sand and gravel pit at East Allentown.

B. Typical Hardyston sandstone quarry, north slope of mountain between Allentown and Bethlehem.

kilns, the hissing machinery and the busy men all unite in telling you that you have reached Kichline's brickyards.'' The plant was in a 15-acre tract of clay land and had a daily capacity of 35,000 bricks. It was started in 1869.

John Nonnemacher and Bros. had a new plant at Twelfth and Liberty streets with a daily capacity of 40,000 brick and a 14-acre tract of clay land.

All of these have long ceased operations.

In 1924 the writer described the brick plants of Allentown in the report on the Mineral Resources of the Allentown Quadrangle.*

C. C. Sensenbach operated a brickyard west of Aineyville in South Allentown from 1890 to 1913. The clay, which contained few glacial boulders, was underlain by fine sand, some of which was mixed with the clay. The plant was operated from April to October each year and made daily 15,000 to 18,000 bricks.

On the south side of Little Lehigh Creek near the Eighth Street bridge in South Allentown Mr. Kichline made brick for more than 25 years. The clay, which contained very few pebbles, ranged in thickness from 4 to 11 feet. It was underlain by rotten limestone, which sometimes became mixed with the clay and caused the bricks to crack while burning.

The Ochs & Frey Brick Co. had two pits in operation near the south end of the Eighth Street bridge in South Allentown until about 1916 and later one pit about a quarter of a mile to the southwest, beyond the Fairview Cemetery. The four kilns of this company had a combined capacity of 870,000 bricks. The clay in the old pits ranged in thickness from 2 to 12 feet and was overlain by about 6 inches of soil. A layer of gravel and sand separated the clay from the underlying limestone. In the pit last worked the clay ranged from 3 to 13 feet in thickness. An electric shovel was used in the digging.

The Ed. G. Mattern brickyard, at Tenth and Tilghman streets, Allentown, was operated for about 60 years. The company ceased operations about 1916 and the site is now occupied by residences. In that time the clay was removed from a large area in northwest Allentown. The clay in most places ranges from 3 to 7 feet in thickness although in a few places it is 12 feet thick. The three kilns had a combined capacity of 500,000 bricks.

Frederick Bros.' brickyard at Fifteenth and Allen streets, Allentown, operated three kilns that had a combined capacity of 700,000 bricks. The clay formerly used was the ordinary residual type obtained from pits near the plant. It ranged from 3 to 12 feet in thickness, was overlain by a foot of loam and underlain by rotten limestone. The clay contained few glacial boulders. The clay last used was taken from an old mud-dam deposit north of the fair grounds at 19th and Tilghman streets. The old iron mine which furnished the clay is now filled. Layers of sand are interbedded with the clay. The clay was dug by steam shovel.

Swoyer Bros. Brick Co. plant, the largest in Allentown, was at Madison and Allen streets. There were six kilns, each of which had a capacity of 305,000 bricks, and the yard was well equipped with dryers and brick-making machinery. The clay ranged in thickness from 3 to 35 feet although clay exceeding 10 feet was seldom found. Pinnacles of limestone that rise nearly to the surface were serious obstacles in the use of steam shovels, but nevertheless such shovels were succesfully operated. The product was sand-faced red brick. This plant ceased operations in 1928 and was dismantled the following year.

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* Pa. Geol. Survey, Topog. and Geol. Atlas, No. 206, 1925.

The largest and most recently operated brick plant in the county was about 1½ miles south of Allentown (pl. 33). It belonged to the Lehigh Brick Co. and was worked for several years. It was closed in 1937 and has been dismantled. The materials used were the residual and glacial clays that cover all the limestones of that section except along the streams. The clay, which varies in thickness from 6 to 20 feet, was removed from a considerable area. In places it was too sandy to use. Residual limestone masses and angular and rounded pebbles and glacial boulders up to 5 feet in diameter are abundant in places. The largest rocks were left in the pit, those several inches in diameter were loaded into the cars by the steam shovel and picked out by hand on the grizzlies, whereas the smaller pebbles were eliminated or crushed by the conical rolls.

The plant was well-equipped with a large stock house, belt conveyors, rotary dryer, centrifugal crusher, 8 round kilns with a capacity of 75,000 bricks each, and 2 long continuous kilns with 22 openings each.

The combined annual output of the brickyards in and near Allentown was large but variable. The bricks were used locally and shipped to places along the lines of the Lehigh Valley R. R. and Central Railroad of New Jersey, especially to Newark, N. J., and to Scranton and Wilkes-Barre, Pa.

The Emaus Brick Co. built a plant at the foot of South Mountain east of Emmaus in 1927 and operated it for several years. The clay used was the residual limestone clay of the region but with considerable glacial clay, sand boulders, and talus from the mountain nearby. The material, on the whole, was unfavorable and the plant has been abandoned.

Clays associated with the limonite iron ores

The descriptions of the limonite iron mines on preceding pages show the presence of abundant yellow, red, white, and black clays associated with the ores. These clays were washed away and carried to artificial settling basins. These deposits are commonly called ''mud-dam deposits.'' At different times the suggestion was made to utilize this material for the manufacture of brick. The most extensive use of this material in the region was in a plant near Bingen, just across the county line in Northampton County. The clay was highly ferruginous and the brick made from this material were quite porous.

Prime says that at Kerschner's mine (107) ''there is a good deal of yellow clay on the top, containing no ore, from which bricks are made.'' (Report D, p. 19)

Martinsburg shales

The only place in Lehigh County where shales are known to have been used for brick manufacture is on the north slope of Huckleberry Ridge. The plant is now in ruins. Weathered Martinsburg shales were used. The product was paving brick. From the appearance of the broken brick about the place, they were of good quality.

The following account of this operation is given in the History of Lehigh County (Roberts et. al. 1914).

> Vitrified Brick Plant.—In 1896, Dr. H. K. Hartzell, William F. Mosser, and Andrew Keck embarked in the manufacture of vitrified brick in the township (South Whitehall), near Guth's Station on the C. & F. R. R. A superior plant was established and a fine circular smoke-stack, 124½ feet high, was erected, with ovens having a capacity of 50,000 bricks; and 15 acres of land with a large deposit of shale material was purchased. Active and successful operations were carried on by them for a number of years. In 1910, a reorganization was effected as the Allentown Brick Co., with H. L. Dougherty as president and J. R. Connelly as superintendent and the business was carried on until 1913. The character of the brick was recognized as superior. (p. 888.)

White clay

The descriptions of the limonite iron ore mines on previous pages contain many references to white clays associated with the iron ores. Since there is a continuous and increasing demand for white clay for a variety of purposes, some attempts have been made in Lehigh County to locate deposits of this material in commercial quantities. So far the prospecting has not discovered pockets of sufficient size to justify the opening of pits. The white clay is commonly in small pockets or lenses associated with yellow, red, gray, and blue-black clays in such a manner that it would scarcely be possible to get any quantity of uncontaminated white clay. However, it is possible that a more favorable locality than any now known may be found.

T. C. Hopkins* says that

> about half a mile southeast of the Friedensville zinc mines is a deposit of white clay in which a shaft has been sunk, it is said, to a depth of 65 feet. The material at the mouth of the shaft, which is now closed up, is a grayish-white, light, powdery clay containing small fragments of hydromica slate. So far as known, no attempt has been made to utilize it, although it has the appearance of being a superior grade of clay. (p. 25.)

White clay was dug some years ago in a line of pits on the north slope of Lock Ridge directly south of Alburtis. Some of the clay about the pits appears to be of good quality. The clay is in the Hardyston formation which is mainly composed of sandstone but with considerable shale in places. Evidently the white clay represents some of the shale bands. Little information concerning the deposits or the operations has been obtained. A few years ago an attempt was made to obtain white clay in the talus and residual shale deposits on the lower slope of Kittatinny (Blue) Mountain north of Slatedale. The writer twice visited the place and examined the material in the pits that had been dug. Only a gray clay was seen and it was so intimately mixed with rock fragments that it could not be obtained profitably. Some local newspapers printed glowing prospects of the venture.

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* Annual Report of the Pennsylvania State College, 1899-1900.

Pottery

In the early settlement of eastern Pennsylvania there were many small pottery establishments in different sections using local clays. There is little existing information as to potteries in Lehigh County beyond incidental reference to several in the south corner. No place in Lehigh County where pottery clay was dug is known to the writer although it is highly probable that there may have been some small local pits that supplied the various establishments.

The clay used in most of the small Pennsylvania German potteries was the residual clay of the red Triassic shales. Some pits in a meadow near Pennsburg, Berks County, furnished the clay for the local potters of Lehigh, Berks, and Montgomery counties for many years. It was considered superior to any clay in Lehigh County. In recent years this clay is reported to be less desirable so that the Stahl pottery is supplied with clay from near Pottstown.

Probably the first pottery in Lehigh County was one established about 1820 by Henry Dubs about two miles northeast of Dillingersville in Lower Milford Township. He operated it until 1835 when he sold it to William Dillinger.

Charles Stahl established a pottery at Powder Valley along Indian Creek in 1840 (also given as 1847) to make tableware. He continued it until his death in 1890. His sons Thomas and Isaac, who had assisted their father, continued the business until 1896. In 1934 they returned to Powder Valley and re-established themselves. Their product, which is of the type made during the past century, is much in demand.

> In 1877 Charles Guth embarked in the business of manufacturing pottery in the township (South Whitehall) along the road one-half a mile south of Guthsville and carried it on for five years. The glazing was reported to be imperfect and therefore the enterprise came to be abandoned. (History of Lehigh County, 1914, p. 888.)

It is not known whether local clay was used as a whole or in part. Potteries are reported to have been located in Allentown and Slatington at an early day.

Fire Brick

Fire-brick establishments are known to have been operated in at least three places in Lehigh County. One was in Catasauqua, another in East Allentown established in 1873, and another at the foot of Gordon St., Allentown along the Lehigh Valley R. R. So far as known all the clay used was brought from New Jersey, particularly from pits near Woodbridge.

SLATE*

By Benjamin L. Miller and Charles H. Behre, Jr.

The Lehigh slate district of Northampton and Lehigh counties has long been the leading slate-producing region of the United States. The slate industry for over 100 years has been the most important industry of nearly all the communities in the northern part of the two counties. A traveler passing through Wind Gap, Pen Argyl, Bangor, Danielsville, Slatington, Slatedale or almost a score of other villages cannot fail to be impressed with the evidence of extensive slate operations as he views the numerous excavations and the ''mountains'' of waste rock that dominate the landscape.

From Pennsylvania quarries and mills all varieties of slate products except slate pencils are obtained. The list includes roofing slate, mill stock, marbleized slate, slate granules, and pulverized slate. ''Mill stock'' is a comprehensive term covering rough or finished slate that is used for structural purposes or in interior furnishings of buildings. It includes slate for structural and sanitary purposes (e. g., sinks, mantels, dripboards, shower stalls, toilet stalls, stair risers, insulating wall board, and the like), grave vaults and covers, billiard table tops, electrical insulation and switchboard material (together classed as ''electrical slate''), blackboards and bulletin boards, school slates, and marbleized slate. Slate granules are used for surfacing prepared roofing, and slate flour as a filler. Among the districts where slate is now being quarried the ''soft'' slate of the Lehigh-Northampton district yields all of these products; the ''hard'' belt in the Lehigh-Northampton district furnishes today only crushed slate, roofing slate, and slate for such structural and sanitary uses as will require no finishing. The great proportion of the slate production of the State is in the form of roofing slate.

Pennsylvania leads all other States in slate production. In 1939 the value of slate produced amounted to $3,056,853 or 45 percent of the value of all slate produced in the United States. Lehigh County made about 10 percent of the output of the State.

Pennsylvania is the only State commonly producing blackboard slate, although very small amounts have come from other localities in certain years. The yield is entirely from the Lehigh-Northampton district. All of the production comes from the neighborhood of Bangor, of Pen Argyl and Wind Gap, or Slatington, Berlinsville, and Slatedale.

History.—Fritts (1877) says that a company for quarrying slate in Northampton County was incorporated in 1805. Finch in 1824 reported that slate quarries had been opened ''near the banks of the Delaware'' but the product was regarded as inferior.

". . . The first operation recorded was in the hard belt by a company from Baltimore which in 1828 began quarrying west of Laurys Station in Whitehall township, probably at the Rockdale quarry, Lehigh County.

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* NOTE: In 1933 this Survey published "Slate in Pennsylvania" (400 pp.), by Charles H. Behre, Jr. Most of the volume concerns the slate deposits and industry of Lehigh and Northampton Counties. Inasmuch as this report is still in print and readily obtainable, it would manifestly be inadvisable to republish any considerable portion of that volume here or to attempt to duplicate this work. For that reason the discussion here is brief and limited to only a few considerations. The account is written by Miller with quotations from Behre's report.

"In 1831 slate was discovered on Benninger's farm, east of Slatington, and probably near the site of the present Genuine Washington quarries, but extensive quarrying on a commercial scale is not known to have been done here before 1844. In that year, according to tradition, the land mentioned was leased by William Roberts and Nelson Labar, who became interested in quarrying from seeing slate outcrops while on a walking trip from Easton to Mauch Chunk."

In 1845 Roberts and Labar searched for slate on the west side of the Lehigh River but failed to find any desirable material. Later Owen Jones discovered some slate on the present site of Slatington and with Roberts opened a quarry about 1845.

"By 1855 the slate quarry industry, stimulated by Welshmen who were instrumental in persuading experienced slaters from Wales to emigrate to this country, was already thriving and growing by leaps and bounds. Indeed in 1850 or thereabouts, Rogers, then State Geologist of Pennsylvania, and his associates found five quarries in operation at Slatington and two more near the Delaware Water Gap, one of the latter apparently being the Old Jersey quarry, east of Delaware River. Rogers even writes of one quarry as having been opened in 1812, but this statement is probably incorrect.

"By 1880, when Sanders studied the district for the Pennsylvania Geological Survey, slate quarrying was in full swing at all the present centers of production. Indeed in many cases Sanders reports large quarries that had been worked out and abandoned."

In 1884 (Mathews and Hungerford) 41 slate quarries had been or were being operated in the Slatington region.

"In its subsequent growth the district has suffered the depressions and revivals experienced by the slate industry of the country as a whole. The introduction of channelling represented a marked advance and served as a stimulus; in 1863 it was first practiced in Vermont and probably reached Pennsylvania a decade later. The appearance, however, of asbestos, paper and tar roofing materials shortly before the peak production in 1903, heralded a general decline in demand for roofing slate. At the same time, school slate consumption suffered greatly through displacement by cheap paper and at the hands of the sanitary experts of our public schools. This was accompanied by an intense price competition among the slate men themselves.

"There ensued, then, a period of marked distress in the industry. Labor costs had risen. Some of the old markets for slate products were on the wane with no possibility of any recuperation in the future; others were being invaded by substitute materials. Freight rates were prohibitive for distance shipments. Added to this, cost accounting was not recognized as furnishing a basis for proper sales prices; expenses were incurred in quarry operations, while prices were being cut in a manner wholly unjustified by the small return on the investment. Then came the greatest of all catastrophies to the industry, the World War. With the entry of the United States, slate quarrying was almost totally abandoned, being classed as unessential; labor was beyond reach. Immediately after our entry into the war the organization of the slate industry, so long projected and so long prevented by internal strife, took place to a considerable degree, and two large companies were formed, one to deal with structural products, the other with roofing slate."

During the past few years the slate industry has suffered greatly, owing to the general inactivity in the building trade and the competition with manufactured roofing products. Investigations to find uses for the discarded rock have met with little success.

Production of roofing slate, 1913-1939

Year	Operators in Lehigh Co.	Squares (100 square feet)			Values in dollars		
		U. S.	Penn.	Lehigh Co.	U. S.	Penn.	Lehigh Co.
1913	31	1,113,944	678,396	143,145	$4,461,062	$2,605,882	$513,027
1914	28	1,019,553	614,863	125,148	4,160,832	2,463,944	461,029
1915	26	967,880	574,223	113,911	3,746,334	2,142,173	401,345
1916	24	835,873	531,342	98,471	3,408,934	2,056,324	367,806
1917	22	703,667	457,393	60,044	3,411,740	2,110,044	280,088
1918	13	379,817	211,196	21,548	2,219,131	1,161,545	118,826
1919	13	454,337	269,580	22,287[a]	3,085,957	1,679,519	135,769[a]
1920	10	396,230	220,366	18,545	3,524,658	1,746,026	144,996
1921	11	348,085	202,605	21,711	3,197,745	1,565,109	157,826
1922	11	479,243	283,365	26,834	4,069,761	2,076,585	188,422
1923	13	507,587	300,272	22,243	4,582,535	2,373,125	171,610
1924	12	469,393	249,450	26,834	4,626,614	2,020,986	218,988
1925	9	494,530	287,120	20,300	5,084,945	2,316,856	178,504
1926	9	465,900	263,668	15,930	5,079,087	2,127,782	127,817
1927	9	468,560	247,120	20,920	4,949,940	1,953,076	149,892
1928	9	483,280	256,540	22,910	5,411,332	2,033,588	158,121
1929	9	462,120	251,880	18,890	4,920,766	1,967,428	135,000
1930	8	340,140	194,700	15,360	3,359,939	1,470,669	99,933
1931	10	277,700	183,600	22,930	2,364,861	1,254,080	127,629
1932	9	144,410	86,550	11,540	1,072,255	439,892	55,952
1933	10	153,170	95,050	13,690	967,834	537,178	66,840
1934	13	137,010	84,690	10,500	1,033,164	585,973	69,887
1935	12	221,630	144,290	16,730	1,456,041	879,209	99,572
1936	9	366,130	235,780	21,490	2,607,402	1,603,734	142,597
1937	9	365,800	219,780	17,350	2,728,109	1,561,731	126,880
1938	10	322,040	195,560	11,850	2,247,910	1,293,426	80,363
1939	10	399,320	236,710	14,730	2,868,961	1,607,929	99,438

[a] Includes some production from Peach Bottom district.

Value in dollars of structural slate produced in Pennsylvania, in 1917-1939

Year	Pennsylvania	Lehigh Co.	Year	Pennsylvania	Lehigh Co.
1917	$710,092[a]	$45,020[a]	1929	$1,135,695	$34,221
1918	686,999	15,518	1930	1,045,237	13,321
1919	676,301	21,670[b]	1931	715,529	23,179
1920	1,005,400	13,170	1932	328,553	16,204
1921	720,462	18,150	1933	203,934	17,039
1922	761,935	19,942	1934	216,086	7,164
1923	885,809	27,086	1935	272,837	11,557
1924	996,460	18,592	1936	349,968	12,203
1925	896,087	30,436	1937	329,141	10,392
1926	997,108	22,172[b]	1938	273,676	5,871
1927	923,888	41,432	1939	271,425	2,796
1928	999,766	31,335			

[a] Includes some electrical slate.
[b] Includes a small production from Lancaster Co.

Production of blackboards and bulletin boards, 1913-1939

Year	Square feet		Value, dollars	
	Pennsylvania	Lehigh Co.	Pennsylvania	Lehigh Co.
1913	3,504,162	1,395,847	$426,703	$147,119
1914	4,021,047	1,711,203	526,846	196,845
1915	3,152,771	905,196	349,959	78,244
1916	3,182,159	706,046	403,502	76,147
1917	2,650,563	674,298	413,163	80,778
1918	1,592,849	298,690	262,221	39,977
1919	1,845,687	223,466	304,251	44,932
1920	2,251,646	321,462	384,131	62,669
1921	3,154,201	604,743	791,241	109,616
1922	3,158,218	518,436	880,596	95,654
1923	4,415,580	543,367	1,186,326	106,883
1924	4,064,520	624,690	1,149,810	126,608
1925	5,083,330	745,890	1,689,336	185,846
1926	3,998,653	768,891	1,356,300	154,079
1927	3,735,870	736,490	1,116,598	162,338
1928	713,840	919,870	1,079,452	194,973
1929	3,562,360	925,120	1,042,771	193,063
1930	3,092,880	690,910	921,735	132,758
1931	2,357,070	682,370	640,593	134,540
1932	1,137,800	288,970	260,706	54,645
1933	625,950	276,200	113,667	36,835
1934	698,730	309,580	163,969	74,844
1935	1,061,360	338,820	260,911	80,448
1936	1,919,340	509,820	434,064	108,058
1937	1,651,010	404,770	357,043	91,188
1938	1,637,570	414,780	347,486	93,030
1939	2,065,830	437,250	500,809	101,602

Value of electrical slate production in dollars, 1918-1939

Year	United States	Pennsylvania	Lehigh Co.
1918	$771,003	$171,880	$83,774
1919	607,796	114,933	64,823*
1920	1,491,769	441,726	176,132
1921	927,951	216,271	103,120
1922	996,322	231,274	128,367
1923	1,754,717	453,070	205,768
1924	1,518,092	366,562	192,149
1925	1,376,948	346,513	210,029
1926	1,537,034	327,447	196,280*
1927	1,155,502	228,559	130,380
1928	1,025,386	211,588	126,456
1929	1,153,396	219,761	135,771
1930	711,578	99,577	64,578
1931	333,082	44,420	31,950
1932	120,514	17,074	14,425
1933	132,295	18,670	10,501
1934	147,280	19,022	16,328
1935	257,625	24,848	22,078
1936	331,639	30,604	25,194
1937	444,887	31,181	28,105
1938	162,793	10,083	6,989
1939	237,001	20,046	14,261

* Lancaster and Lehigh counties.

Value in dollars of school slate produced in the United States, 1913-1939

Year	United States	Lehigh Co.
1913	$51,313	$34,329
1914	35,205	26,897
1915	38,167	25,861
1916	52,561	33,495
1917	48,828	28,012
1918	17,016	6,953
1919	54,635	31,992
1920	82,989	62,749
1921	56,170	42,591
1922	42,027	30,105
1923	31,102	21,016
1924	27,348	23,702
1925	35,818	34,564
1926	32,886	32,521
1927	$19,998	$19,257
1928	22,591	22,591
1929	20,371	20,371
1930	19,230	19,230
1931	16,237	16,237
1932	3,418	3,418
1933	5,887	5,887
1934	5,499	5,499
1935	9,150	9,150
1936	6,818	6,818
1937	11,930	11,930
1938	13,179	13,179
1939	5,769	5,769

School Slates

Lehigh County has the distinction of being the only county in the United States where school slates are now being manufactured. The first school slate factory in the United States was started by James and Roberts in 1847 on Factory Street in Slatington. Other sections produced them for some years but the disuse of individual school slates in the public schools has caused the contraction of the industry to its present condition. Certain beds in the Slatington-Slatedale district furnish the most desirable material. Two companies, the National School Slate Co. and the American Slate Works, are active. The former obtains part of its slate from its own quarry, the Blue Ridge Quarries, but also purchases from some of the other quarries of the region. The latter company does not operate any quarry but buys from different concerns that obtain material of the necessary quality. In every case the soft black variety desired constitutes only a small part of the quarry product. The qualities that fit it for school slates render it unfit for roofing purposes in that the conspicuously black color is not permanent but fades on exposure to sun and rain.

Toy blackboards and bulletin boards are made from the same kind of slate. The toy blackboards are mainly marketed by the chain stores. School slates are nearly all exported. They go to the Central and South American countries, to the Netherlands East Indies, and South Africa. Italy and Germany in previous years supplied a considerable part of the demand but since the outbreak of the European War in 1939, Lehigh County has had little competition in the school slate industry of the world. The production in 1940 of 1,604,272 pieces considerably exceeded that of 1939, and the 1941 production is expected to show further gains. The two companies market a variety of products in various sizes and frames. One common slate has one side lacquered in white for the use of colored crayons.

School slates are made from beds darker than the usual light-gray slate, but not as dark as the "ribbon" or highly carbonaceous layers. The slate is split, like roofing slate, and then trimmed with a rapidly rotating saw shaped like a square with a triangular prolongation at each corner. The sizes of school slates vary from 4 x 6 inches to 9½ x 14 inches. "Toy blackboards" measure 18 x 20 inches.

Each piece of slate is first sent through a beveler; this bears a carriage by which the slate is propelled over knives which have their blades inclined in such a way that one edge of the slate is beveled in transit.

When the piece has been beveled on all edges, it is forced between two knives placed with their blades only far enough apart to permit the passage of the desired thickness of slate (1/6, 1/7, and 1/8 inch, according to the grade specified). This machine is called the shaver.

For the final surfacing the beveled and shaved slate may be passed between two paper covered cylinders which rotate rapidly in opposite directions; this machine acts as a buffer.

Some slates are ruled, especially if destined for use in Continental Europe. The grooves of the rulings are colored with red lead. The last step before framing is a thorough washing.

School slates destined for domestic use are framed here as well, and a bit of colored goods is applied to the outside of the frame. Foreign slates are set in wire-bound frames. The finished slate is carefully packed in boxes.

In recent years two school slate factories have operated between Slatington and Slatedale. (Behre, 1933.)

The 1940 price of the rough material sold to the school slate factories by the quarry operators is \$14.00 per thousand for the 7″ x 11″ size, which is the standard. The 6″ x 9″ size is \$12.00 and the 9″ x 13″ is \$16.00. At times it is difficult to obtain the material from the quarrymen.

Five different slate quarrying districts are recognized in Lehigh County.

1. Slatington—75 quarries in Lehigh Co., 54 in Northampton Co.
2. Lynnport—20 quarries in Lehigh Co., 8 in Berks Co.
3. Treichlers—7 quarries in Lehigh Co., 5 in Northampton Co.
4. Lowhill—4 quarries in Lehigh Co.
5. Walberts—1 quarry in Lehigh Co.

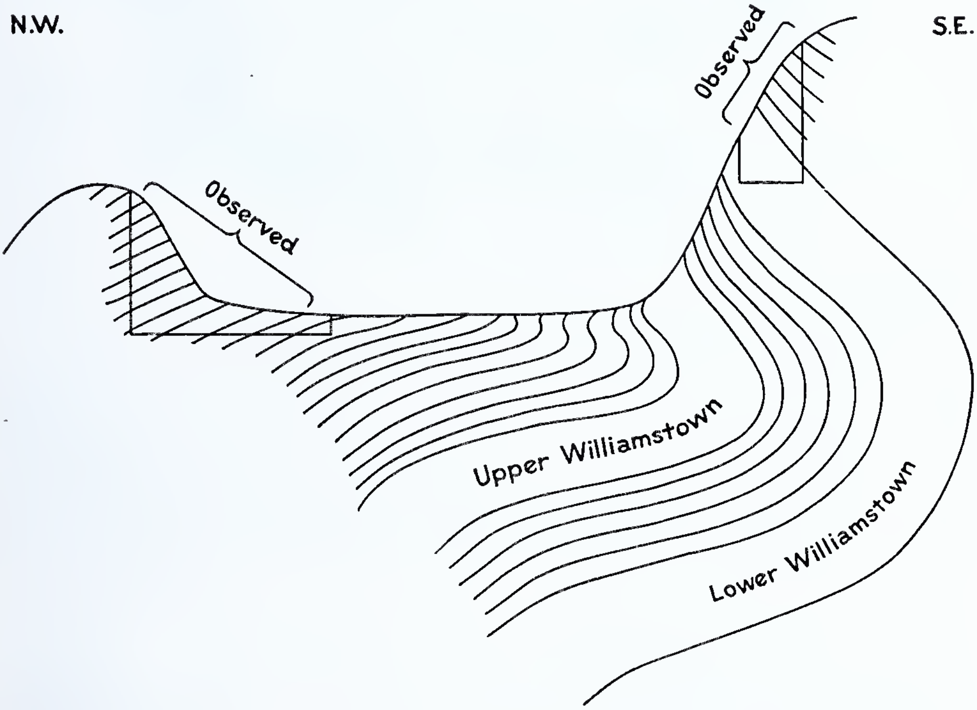


Figure 14. Section across eastern Hughes quarry, between Emerald and Slatington, to show inferred structure.

Slatington Group.—The quarries in this group occupy an area the longer extent of which is northeastward, passing from Slatedale in Lehigh County and west of the Lehigh River eastward through Slatington, Walnutport, Berlinsville, and Danielsville. Slatington, with a population of about 4000, is the dominant town of the district; the quarries farthest away from it—those at Danielsville—are at most seven miles distant. All quarry operations have rail connections with Slatington by the Lehigh Valley, Reading or Lehigh & New England railroads.

The quarries of the Slatington group are opened in the soft slate or upper member of the Martinsburg formation and in the same beds as those of the Bangor, Pen Argyl, and Slatefield groups of the eastern part of this district.

In structure the Slatington region differs from the Bangor-Pen Argyl region in that the folds have axes that are more nearly vertical, so that individual beds are brought to the surface on both sides of the axis. In some sections transverse to the regional strike, beds are repeated not once only, but again and again; the result is a complex outcrop pattern suggesting, though on a far smaller scale of course, that of the Appalachian Valley. The number of fold axes, too, is far greater than recognized at Bangor and Pen Argyl. In a section along Lehigh River between the first slate outcrops at Slatington and Lehigh Gap, twelve anticlinal axes and eleven synclinal ones are recognized and there are certainly several more which are not exposed. The most prominent and persistent of these are the Prudential, Empire, Cambridge and Eureka synclines which are exposed in or near the quarries after which they are named. The Prudential and Eureka synclines extend completely across the Slatington region.

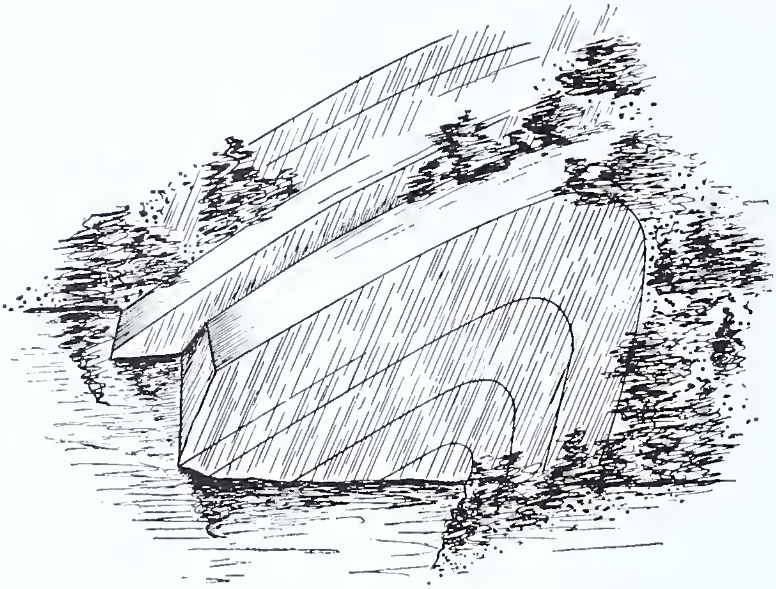


Figure 15. Sharp anticline, with northwest overturning, as seen in southwest wall of Lehigh Gap quarry. Width shown about 30 feet.

Individual Quarries in the Slatington District

In "Slate in Pennsylvania" all known quarries in the county are described. It seems inadvisable to republish all of these descriptions but descriptions of certain selected ones are given. All active quarrying is now confined to the Slatington district.

Locke and Royal Blue Quarries. About 800 feet north of the Slatedale Hotel are four quarries, which are so close together that they are grouped under one number. With respect to each other, they lie along the regional strike. The western is the Locke quarry and the three easterly are generally referred to as the Royal Blue openings.

The Locke quarry is an irregular opening, roughly in the shape of a rectangle with the west corner truncated, and measuring about 500 feet by 350 feet in maximum dimensions. The greater part of the hole is full of water, but in 1927 work was being done along the northwest edge.

Near the southwest corner the beds strike N.65°E., and dip steeply north but along the northwest edge the dip is gentler, here only 52°. Strike and dip of cleavage is N.74°E., 65°S. The inference is that an anticlinal crest lies some distance to the south and a synclinal crest immediately north.

The beds exposed are the Lower and Middle Locke big beds in the southwest part of the opening and the Upper Locke (or Manhattan) big bed on the north piece mentioned. The latter is here about 20 feet thick.

This quarry is equipped with two mills, a larger one south of the quarry for making structural slate, and a smaller just north of the opening for rough trimming. The chief products are electrical and structural slate. The quarry is one of the oldest openings at Slatedale. The present operating company is the Shenton Slate Company of Slatedale.

The three openings east of the Locke quarry are referred to as the Royal Blue quarries and are also known, beginning at the west, as the Shenton No. 2, Crescent, and Royal Blue quarries respectively. The Shenton No. 2 measures 225 by 210 feet and is 35 feet deep to water level. The Crescent is 240 by 215 feet, with a tunnel in the northwest side. The Royal Blue lies just west of the highway; it is 375 by 225 feet in surface area and is about 220 feet deep; in 1927 the chief operations centered around tunnels driven into the overhanging northwest side of the opening.

Structurally the situations in the three Royal Blue quarries are identical. The beds generally strike N.75°E.; along the southeast sides of all three openings, which are essentially parallel, the dip is 75°N., but it flattens northward and downward and in the eastern tunnel of the east opening it is only 8°N. This flattening of the beds indicates a synclinal axis which outcrops between the Royal Blue openings and the Manhattan quarry to the north. The cleavage is roughly parallel in strike to the beds, but dips 62°S. Grain trends N.25°W.

The beds opened include the two lower big beds of the Locke "run," but the openings are not carried far enough to the north to intersect the uppermost Locke big bed on the north edge of the Locke quarry. The Lower Locke big bed appears on the south edge of the opening.

The synclinal axis here defined pitches east, as bedding and cleavage strikes intersect westward. Another interesting feature is the series of branching and gently dipping joints, which intersect the bedding planes so as to form acute dihedral angles which open upward to the south and downward to the northwest. These have introduced serious difficulties in tunnelling. Near the northwest edge a "loose ribbon," along which some movement has taken place, has also given trouble, particularly because of the associated joints.

The mill is south of the opening. Products include structural and electrical material and some ribboned slate.

These three quarries were opened about 1900 under different management. The eastern pit is now the only one in operation.

Kern Quarries. Three quarries lie on the eastward continuation of the strike passing through the Royal Blue quarries, and 200 feet east of the latter. The three openings are about equal in area—approximately 100 by 150 feet or less—but vary in depth; thus the east quarry is said to be 230 feet deep, whereas the west opening when visited in 1927 had attained a depth of only 90 feet. The two easterly holes are abandoned and filled with water, the west one alone being operated.

In the latter opening there are 10 feet of glacial overburden, beneath which the slate beds strike N.73°E., and dip 71°N. at the northwest edge, 81°S. at the southeast edge. At the north edge is the Middle Locke big bed and the Lower Locke big bed is just south of the southeast edge. The cleavage strikes N.75°E., dips 60°S.

An interesting fact in connection with this opening is the method of drainage. Water runs east into the next hole, which is deeper, along cleavage and joints, and the quarry company pumps from the east of these two openings to maintain the eastward drainage gradient.

These quarries are in the hands of the J. P. Kern Slate Company of Slatedale. Equipment includes two mills, one at the quarry for trimming and rough dressing, and one for finishing at Emerald. Products include structural, electrical, and roofing slate, and some school slate; for trimming the latter, circular saws, 7½ inches in diameter with 12 teeth, are used, instead of the square saws more commonly seen.

The two quarries to the east show a structure like that described above; the eastern one opened the Lower Locke big bed in addition.

Blue Mountain Quarries. These are two openings just north of the highway and about 3400 feet by road from the Slatedale Hotel. The west (Quarry a) is a small hole about 90 feet square, showing 45 feet of slate above water level. Tunnels are said to have been driven into its northeast and northwest walls, the latter tunnel serving for drainage. One big bed (the upper one exposed in Quarry b, described below) is seen at the southeast edge. The beds strike N.75°E. and dip 43°N.; cleavage strikes similarly but dips 70°S.; the structure is thus the north limb of an anticline. The quarry is not now being worked. It is used for the disposal of waste from the opening to the east.

Quarry b is a large opening, roughly rectangular, measuring about 400 by 200 feet and 125 feet deep. It exposes the anticline mentioned in describing Quarry a and the complementary Prudential syncline to the south. In the west corner at a depth of 50 feet the beds strike N.70°E. and dip 4°N.; near the middle of the opening the dip on the working level is 30°S.; and at a depth of 60 feet along the southeast wall the dip is vertical. Thus the crest of the anticline mentioned in describing Quarry a, as well as the trough of the complementary syncline to the south are defined. The syncline has an axial plane striking N.83°E. and dips 55°S. and the fold pitches 5°E. There are three big beds, of which the upper (also seen in Quarry b) is 13 feet thick and the middle and lower are respectively 22 and 6¼ feet in actual thickness. Besides being worked in the quarry bottom, the lowest big bed is mined along a tunnel in the northeast wall, but it rises so as to pass into the southeast quarry wall as it is followed south.

Near the trough of the syncline there is pronounced false cleavage on planes striking N.75°E. and dipping 43°N., accompanied by the usual curvature of the cleavage planes. Here also there is a "loose ribbon" (movement on the bedding plane), along which are numerous small, closely spaced, calcite-filled joints striking N.5-15°E., and standing more or less vertically.

This quarry is equipped with a small mill, consisting of a two-story building, the upper floor being used for lumber stock and as a repair shop. The present production includes structural slate, blackboards, and electrical slate, and some roofing slate.

The Blue Mountain quarries were opened in 1860 and since then have passed through many hands. At present they are operated by the Blue Mountain Slate Company, which acquired the property in 1898. (The pit has been idle since 1938.)

Blue Valley Quarry. This large, irregular opening is the west one of several extensive quarries situated about half a mile northeast of Rextown. Its maximum areal dimensions are about 685 by 400 feet, and some 40 feet of slate are visible above water level, covered by a thickness, locally amounting to 30 feet, of glacial till.

This opening shows two close folds, the Eureka syncline and the complementary anticline to the south. Both are tipped northward, so that the axial planes, which strike about N.75°E., dip 60-65°S. The anticlinal axis emerges at the surface about 255 feet north of the southeast edge of the quarry and the synclinal axis about 250 feet farther north. At the northerly edge of the opening there is evidence that the beds are flattening again near a second anticlinal crest.

Three big beds are seen here. One of these comes to the surface at the extreme southeast corner of the opening on the south limb of the anticline, intersects the surface once more on its north limb at about the middle of the opening, and reappears at the north edge on the north limb of the syncline already described. This is the Upper Star (Upper Empire, Upper Eureka) big bed. The next big bed below, which just fails to reach the surface at the northwest edge of the opening can be correlated by measurement with the lower big bed in the Empire quarry. The highest big bed exposed is that preserved in the syncline,—the Klondike or Lower Locke big bed also seen in the Locke, Royal Blue, and Kern quarries at Slatedale.

Shattered drill cores suggest the presence of a zone of movement at depth in the northwest end of the opening. This quarry was first opened about 1875. Subsequently it passed through many different hands until it came into the possession of the Blue Valley Slate Company, the present owners. It was shut down at the beginning of the World War. Recently exploratory drilling has been carried on at the north edge of the opening.

The mill and finishing equipment at the north end of the quarry were being leased to the Keystone Slate Company by the owners of the Blue Valley quarry, when visited in 1927.

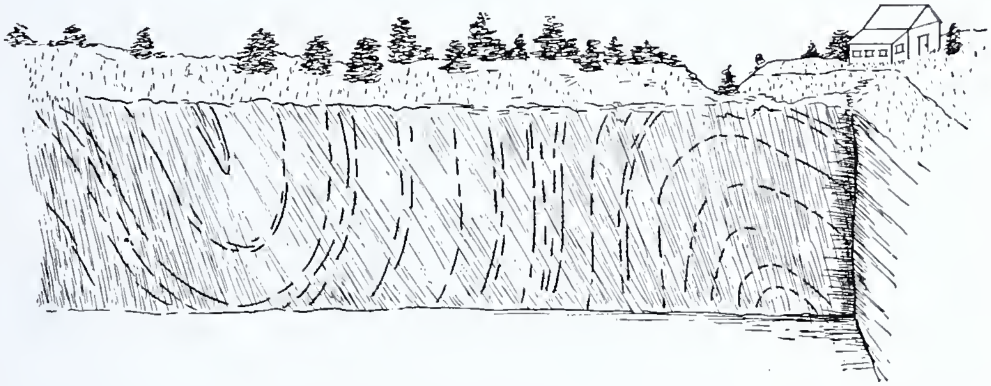


Figure 16. Typical folding of the slate beds, as illustrated in the east wall of the Eureka quarry near Slatington.

Eureka and Mountain Quarries. Three quarries lie close together about 1200 feet east of the Blue Valley quarry and on the strike continuation of its structure and beds. Beginning at the west, they may be designated a, b, and c.

Quarry a is the Old Eureka quarry. It is rhomboid in shape, and about 200 by 350 feet in size, with the longest dimension northwest. Depth to water level is about 135 feet. Beneath 8 feet of glacial overburden bed rock is exposed. This shows the same two folds noted in the Blue Valley quarry. The axial planes strike somewhat more northerly here, approximately N.65°E. Detailed observation in the syncline shows that the cleavage planes flare, fan-like, downward. In this fold joints striking N.70-80°E. are seen to dip 5-15°S. on the south limb and 10-20°N. on the north limb; their attitudes thus appear to be definitely related to the folding. At the north edge there is again the flattening observed in the Blue Valley quarry, for the beds strike N.72°E. and dip only 35°S.; evidently the anticlinal axis mentioned in describing the Blue Valley opening is not far north of the northern edge of the Old Eureka quarry.

The strata exposed include the same three big beds as at the Blue Valley quarry. The Lower Star is the highest bed of the anticline to reach the surface; the Klondike is the big bed in the synclinal axis; and the Upper Star outcrops midway between the two.

This quarry is not now operated.

Quarry b is smaller, being approximately 125 feet wide and 210 feet long. It is the New Eureka quarry. As this opening lies only about 100 feet east of the Old Eureka, and directly along the strike continuation, it shows essentially the same structure, the Lower Star big bed coming to the surface at the anticline. Quarrying has not been carried far enough north to expose the Eureka syncline, however, and so the Klondike big bed is not worked, the clear stock being furnished by the Lower and Upper Star big beds.

Near the axis of the anticline prominent openings parallel to the beds are filled with quartz. Here, too, numerous joints are observed striking parallel to the axis and dipping generally about 20°N. or 20°S., in this respect resembling those mentioned in describing the Old Eureka opening.

The mill equipment includes two roofing slate shanties, two school slate saws, and the usual trimming saws, planers, and rubbing beds. An accessory mill serves for polishing only. In 1928 the quarry was operated by the Slatington Slate Company, which took it over in 1917 and has operated it continuously since.

Quarry c is called the Mountain quarry. Though one opening when its outline at the surface is considered, this is really two separate holes into bed rock, of which the west is a shaft about 60 feet square and the east a larger irregular quarry with maximum dimensions 345 by 150 feet and 150 feet deep. The two together show what might be anticipated from their location with respect to the other quarries just described. In the shaft the anticline of the Eureka quarries alone is seen. In the larger opening, however, work has been extended far enough northward to expose the syncline as well. Here the beds on the north anticlinal limb are seen to be greatly thinned by compression. The synclinal axis appears at the surface 85 feet south of the northwest edge, the Klondike big bed here measuring 18 feet in actual thickness. In addition to quarrying, tunnelling along the strike has been resorted to for working the Upper Star big bed.

The Mountain quarry, though controlled, like the Eureka, by the Slatington Slate Company, was not being worked when last visited in 1927. This company actively operated the two openings between 1901 and 1918, however. The Mountain quarry is said to have yielded 80,000 squares of roofing slate.

At present (April 1941) the Eureka and Mountain quarries are idle. However a pillar of slate separating the Eureka pit from the most westerly of the Mountain (Mountain Bangor) quarries is being worked by Roberts Brothers. They are producing roofing slate.

The Fairview Slate Co., successor to the Slatington Slate Co., owns the Mountain quarries but is not working them. They are running the factory near the quarries and producing blackboards and electrical slate from slate from the shaft now in operation about a mile to the southeast.

Blue Ridge Quarries. These two openings are about 1200 feet northwest of the National School Slate Company's mill and roughly a mile due east of the Rextown crossroads. Eastward from them in turn lie two large quarries, the Pennsylvania-Star and the Old Cambridge.

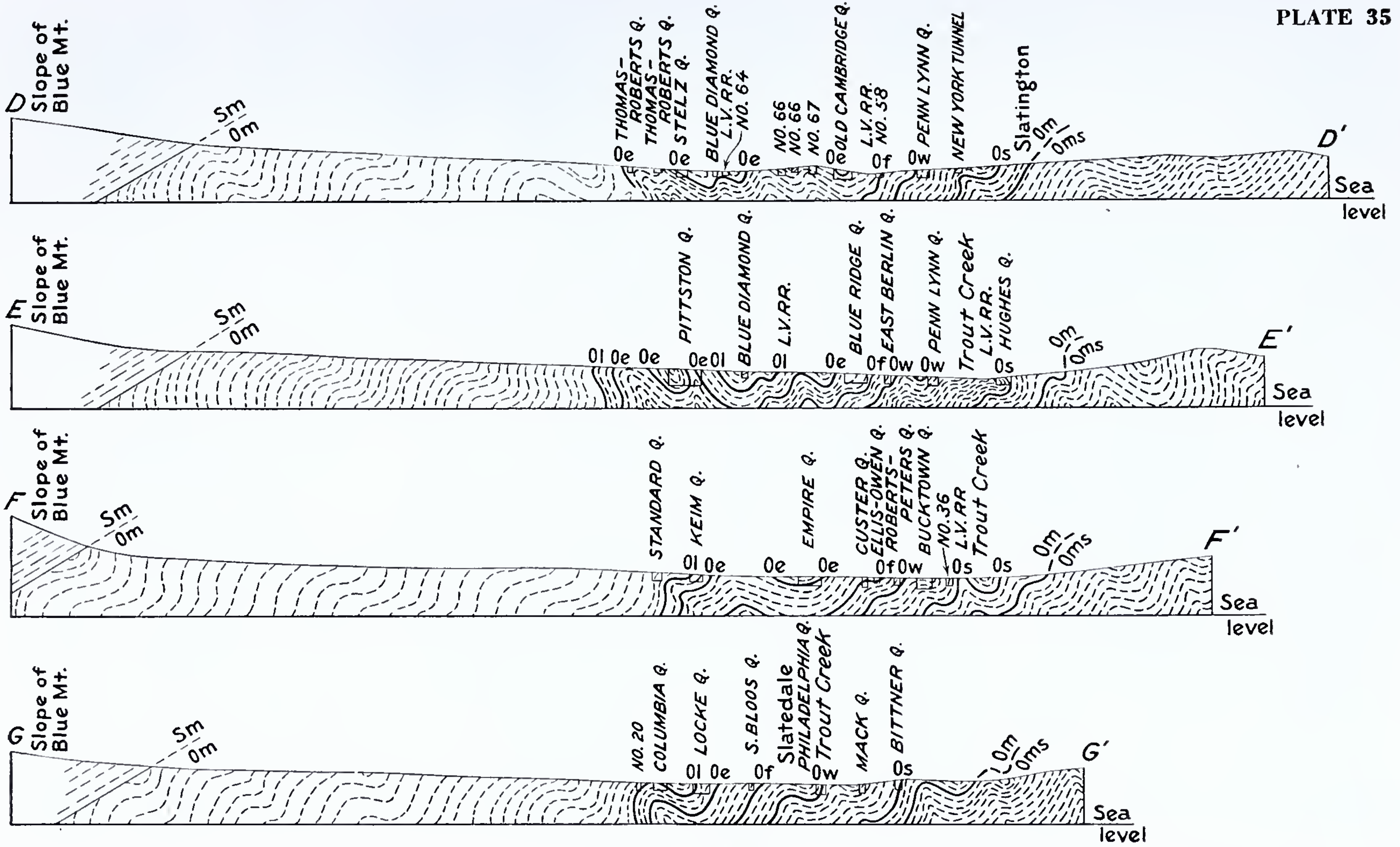
The Blue Ridge quarries include a large westerly opening and a smaller hole in which operations were just beginning in 1927. The west opening is now abandoned; a serious cave-in of slate and overburden on the southeast side ended operations some years ago. It measures 225 by 275 feet at the surface. An exceptionally heavy cover of glacial till lies above the bed rock, necessitating extensive stripping which extends from 25 to 50 feet back from the edge of the opening on all sides.

Some 90 feet of slate are exposed above water level. At the northwest side the beds strike about N.70°E. and dip 28°S. On the southeast side the strike is similar but the dip is 82°S. In both places the cleavage strikes N.70°E. and dips 64°S. These surface observations are consistent with the structure seen in the northeast wall of the quarry, for this exhibits a syncline the axial plane of which emerges 125 feet south of the north corner and strikes and dips like the cleavage. As remarked elsewhere, the cleavage planes radiate downward in the trough of the fold.

The quarry is opened in the two big beds of the Star "run." The Lower Star big bed just reaches the quarry bottom in the trough of the syncline. The axis here appears to pitch west only very slightly and probably assumes an eastward pitch still farther west, to judge by areal relationships.

The quarry hole operated at present has a depth of 120 feet and surface dimensions of 85 by 125 feet. It shows the south limb of the northward tipped syncline exposed in the larger quarry, for the beds at the surface

PLATE 35



Structure sections at Slatington and Slatedale.

dip 80°S., and in the bottom at the northwest edge they dip 55°N. Cleavage strikes N.75°E. and dips 67°S. Grain trends N.37°E. and dips 82°E.

Many joints are observed, with strikes parallel to the strike of the cleavage and north or south dips that are rarely in excess of 45°. The joints of this south synclinal limb flatten strikingly to the south and steepen northward. They are the loci of considerable weathering which takes the form of "rusting." Jointing is most marked in the larger beds.

The beds worked are again the two big beds of the Star "run." School slate is made from some of the darker beds.

Equipment includes two mills, one for making school slate (the National School Slate Company's mill) and the other situated southwest of the old quarry, for making roofing slate and some school slate.

Most of the production from this quarry goes to the factory of the National School Slate Company, the largest school slate producer in the United States. This is located on the west outskirts of Slatington, north of Trout Creek.

Cambridge Shafts. Three small shafts, each about 30 by 50 feet in surface area, lie just south of the Ridge Road, some 2000 feet northwest of the Slatington post office and 100 feet apart. The east shaft is 195 feet deep; the two westerly ones show the same dimensions; they are reported to be 220 and 225 feet deep, but were not being worked and were therefore inaccessible in 1927.

At the surface in the east shaft the beds strike N.70°E. and dip 27°S., whereas the cleavage strikes like the beds and dips 82°S. In its descent the shaft passes through the Upper Franklin big bed and, after traversing 29 feet of "ribboned" slate, it encounters the Lower Franklin big bed, here 23¼ feet in actual thickness. In the shaft this bed strikes N.80°E., dips 11°S. It is followed northward by a tunnel 275 feet long in 1927. Whereas the tunnel remains horizontal for some distance north of the shaft, the bed continues to rise, until its top is above the roof of the tunnel. This is at a distance of 175 feet from the shaft. Beyond this point, however, the beds dip northward and the tunnel now is driven on a slope so as to follow the dip of the bedding, which averages about 17°N. for 100 feet, where the "breast" was located at the time when this field work was done. The fold with crest as described appears to pitch west at a gentle angle.

The cleavage strike is N.71°E., and the dip is 85°S. Jointing is common. The fractures are of two sets, one virtually horizontal, the other striking N.70°E. and dipping 35°N. Locally these latter shatter the slate greatly, making the underground operations hazardous.

The width of the tunnel-incline is about 100 feet parallel to the strike. In breaking the rock neither drilling nor broaching are resorted to, only explosives. Two accessory pulleys are used for hauling large blocks out to the shaft from the "breast."

Surface equipment includes a mill, roofing slate shanties, a storage shed for roofing slate, a boiler house, and a good blacksmith shop. The three shafts have been operated since 1912 by the Cambridge Slate Company. They represent true underground mining of slate.

The Cambridge shafts have been idle until recently but a new shaft is now being operated by Bachman Brothers.

Shaft of Fairview Slate Co. The most important new operation in the Slatington district since the publication of Behre's report in 1933 is the shaft of the Fairview Slate Co., formerly the Slatington Slate Co. It is located a short distance east of the Cambridge shafts of Bachman Brothers. The shaft was sunk after considerable core drilling had been done to determine the depths and the quality of the Franklin beds underlying the property. The untimbered shaft is 175 feet deep. The Lower Franklin bed, which here is 32 feet thick, is being worked. One drift is about 200 feet in length and another 375 feet. The main output is roofing slate. Some blackboard and electrical slate is produced at the factory of the company located near the Mountain quarries. The blocks are hauled there by truck. Operations started about 1929.

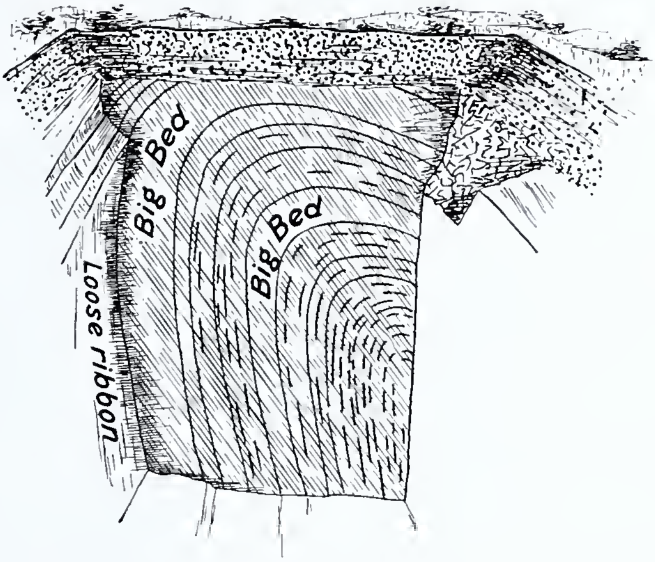


Figure 17. Fold in northeast wall of Manhattan quarry near Slatedale.

Lynnport Group.—The quarries of this group are in the valley of Ontelaunee Creek and its tributaries, scattered over an area about eight miles long in a northeast direction and two miles wide, which lies parallel to and south of the top of Blue Mountain, and north of the crest of Shochary Ridge. Several small towns, including New Tripoli, Lynnport, Wanamaker, and Steinsville are in or near the quarry region, along the line of the Schuylkill & Lehigh (Reading) Railroad. The quarry production could find an outlet over this railroad, either by trucking to the main tracks or by means of railroad spurs; in no case are the openings more than three miles by road from the railroad.

All of the quarries of the Lynnport group are now abandoned. They lie in what the writer believes to be the "soft" or upper slate member of the Martinsburg formation. These slate beds may well be the equivalent of the ones worked at Slatedale and eastward, but the basis for exact correlation is not available.

West of Slatedale the contact between the upper Martinsburg and the sandy middle member suggests the relatively simple structure of repeated, roughly isoclinal folds. At Mosserville, at the eastern end of the Lynnport region, however, there is an abrupt southward bend, suggesting, if the sandy beds north of Mosserville underlie the "soft" slate, that there is just north of Mosserville an anticline of the sandy layers that pitches west; south of this fold, between Mosserville and New Tripoli, there appears to be a syncline of the "soft" slate, also pitching west. These two structures give the sigmoid geologic boundary line between the upper and middle members of the Martinsburg that is seen on the geologic map. For a discussion of the detailed observations upon which this structural hypothesis is based, the reader is referred to the description of quarries 26 and 28 given below. Further, most of the folds west of Slatedale, at their western exposures, show a slight westward pitch, which is consistent with the westward pitch recognized at Mosserville.

Attempts to correlate the beds exposed in the quarries of the Lynnport group with those of the Slatington region have not met with success, partly, perhaps, because this matter received very little attention, partly because of the limited exposures. It is at least possible, however, that the equivalence of the strata in the two regions might yet be definitely established if due allowance were made for changes in relative thickness along the strike. One difficulty is introduced by the fact that the southern edge of the slate belt in the Lynnport region is bounded by the Eckville fault and it is thus altogether likely that some of the lower slate beds have been "cut out."

Though now no longer important, the quarries of this region were once actively worked and contributed materially to the slate production of the State. It is not probable that they will experience a revival in the near future, however. The yield formerly included almost all types of "soft" slate products,—roofing, blackboards, electrical slate, structural material, and even marbleized slate; there is no recorded production, however, of pulverized or crushed slate, slate pencils, or school slate.

Treichlers Group.—Near the northeast edge of the Slatington quadrangle, in Whitehall and North Whitehall Townships, Lehigh County, and in Allen and Lehigh Townships, Northampton County, are twelve isolated slate quarries. All are in the lowest member of the Martinsburg formation except the Rockdale quarry. Some lie close to Lehigh River and therefore would have ready access to the Lehigh Valley and Central of New Jersey railroads, but a few are so far away from these means of transport that their operation would probably necessitate trucking. All are now idle.

All of the quarries of this group are in closely "ribboned" slate, but the angle of intersection of bedding and cleavage is generally so low that very little banded slate has been produced. In many places certain slate beds, especially those that are slightly coarser in texture, break free, and thus a piece is obtained one large surface of which is a bedding plane, and the other represents the cleavage. Such pieces are satisfactory when small slates are desired, but when large ones are needed the thicker end becomes undesirably heavy.

Walberts Group.—The southeastern edge of the Martinsburg formation in Lehigh County shows a series of arms or tongues projecting eastward into an area underlain by earlier limestones; locally these tongue-like forms become completely cut off from the main area of the Martinsburg formation, constituting outliers. The structural reasons for the appearance of such more or less isolated areas of the Martinsburg within the Ordovician and Cambrian limestones have not been worked out.

One of these, resulting probably from infolding, is Huckleberry Ridge, in the east central part of the Slatington quadrangle. The westward-pitching syncline, to the presence of which this mass of Martinsburg slates can best be attributed, has preserved some hard slate in a single quarry, though several clay pits have been worked in the associated shales, as a quarter of a mile north of Wennersville and a mile north of Walberts.

This quarry has not been worked for 50 years or so. It is mentioned by Sanders as being idle as early as 1880.

About half a mile west of Lanark in the Saucon Valley a small amount of the Jacksonburg cement rock was quarried at one time under the misapprehension that it was slate. The common report is that it was used for roofing purposes. It is obviously ill-fitted for such use.

SAND AND GRAVEL

The local demand for sand and gravel has resulted in the development of many deposits that in a less populous section would be disregarded. Four kinds of sand are dug, each of which is distinct in origin and occurrence and adapted more or less to different uses.

Decomposed gneiss.—The most unusual sand of Lehigh County is that obtained where the lighter-colored quartz-feldspar gneisses have decomposed into a mixture of angular particles of quartz and impure kaolin. Technically, decomposed gneiss should not be called sand, but in this section, where such material is used as a substitute for the ordinary kinds of sand, the commercial usage seems to be justified. The alteration of the feldspar to kaolin and the oxidation and removal in solution of the hornblende and pyroxene causes the rock to disintegrate. As water carrying oxygen in solution is the most active factor in this change, the decomposition starts along the joint planes of the gneiss and gradually extends into the blocks bounded by these fissures. Near the surface the alteration is more complete, and the rock is soft enough to crumble into sand when disturbed. At greater depths many masses of partly altered rock are still so hard that they must be discarded when the material is quarried for sand. In some of these quarries these resistant blocks are passed through a rock crusher and screened, the finest portions being used for sand and the remainder for concrete work or road metal.

The gneiss sand pits, as shown on the map, lie along the slopes of the gneiss hills, especially near Farmington. Besides those shown on the map there are other openings where at times a few wagonloads of sand have been dug.

The pits that are opened along the sides of the mountains increase in depth as the work progresses, and in some of them a 60-foot face is obtained. In some places the rock is decayed sufficiently to furnish sand at depths of 100 feet or even more.

In most of the pits less than four feet of overburden must be removed. It is loamy clay and fresh gneiss boulders derived from the outcrops of gneiss higher up the mountain. The quarrying is done with pick and shovel, and the loose material is thrown against a sloping screen, the mesh of which differs according to the kind of sand desired. The particles that fail to pass through, roll to the bottom of the screen. By pounding these coarser fragments with the back of the shovel many of them can be disintegrated sufficiently to pass through the screen when they are again thrown against it. The tough pieces are thrown aside as waste or put through a stone crusher.

In some of the pits the decomposition of the gneiss is very irregular, and certain parts of the pits must be abandoned on account of the large amount of waste rock. In one place the gneiss may be thoroughly decomposed to a depth of fifty feet, and close-by hard fresh rock may come within a few feet of the surface. A few pits contain dikes of basic rock, which must be discarded.

The gneiss sand is used for a variety of purposes. It is well adapted for a molding or core sand on account of the kaolin, which acts as a binder, and large quantities have been used by the furnaces, foundries, and pipe mills of the region. For plaster and mortar it is less desirable, as the presence of the kaolin is detrimental, but this is partly counterbalanced by the sharp angularity of the grains of quartz, which increases the strength of the plaster or mortar. The decomposed gneiss has been used widely as a building and brick sand throughout the region. The coarse material has been used extensively in concrete work and to a less extent for road metal.

The prices of the sand depend upon both the quality and competition. The waste material used for road work sells for a very low price. The market is almost entirely local, although some sand has been shipped to foundries and furnaces outside the county. The production, which varies greatly from year to year, has been small recently.

Glacial sand and gravel.—Although an ice sheet covered a considerable part of Lehigh County, workable deposits of glacial sands and gravels are comparatively few. Most of the glacial deposits of the region consist of clay and boulders.

The glacial gravels and sand are well stratified and consist mainly of well-rounded quartz or siliceous sandstone in a matrix of loose quartz sand. In some places the sand predominates, but in most places the sand is subordinate to the gravel.

In the deposit northeast of East Allentown (pl. 39-A) that was worked by M. H. Bachman & Co., the upper 5 feet consist of plastic brownish-yellow clay, beneath which are well-stratified pebbles, the largest 3 inches in diameter, though the average is less than 2 inches. The matrix consists of loose quartz or loamy sand. Lenses of fine sand free from pebbles are present in parts of the deposit. The pebbles consist mainly of siliceous sandstones and conglomerates, but pieces of limestone and rotten shale are not uncommon. Boulders several feet in diameter occur at the base of the section. The deposit is from 40 to 50 feet thick and rests on decayed limestone. It was worked by a cable excavator, the gravel being scooped up by a bucket and carried on a cable to the crusher house, where it was crushed to the size desired. Most of it was ground to a sharp sand which was well adapted for plastering, brick laying, and concrete work. Some of the coarser material was used for roads. The annual production was about 20,000 tons.

Similar gravel seems to extend continuously to West Bethlehem, where a pit that is widely known as Rauch's gravel pit was operated for many years. The National Guard Armory now occupies part of the old pit. The following section was exposed in 1883:

Section at Rauch's gravel pit.[*]

	Feet
Clay holding boulders, large and often sharply angular, lying irregularly in the body of the clay. Of this clay there remains on the hill top, as quarried	4
Gravel and sand, horizontally stratified; destitute of boulders; the pebbles all water worn, none more than 3 or 4 inches long.	
Streaks of pure sand.	
Sand with oblique stratification.	
Gravel and sand, stratified, but not horizontally, gray, sandy, no clay.	
Bottom of pit	30+
	34+

Two wells in West Bethlehem show that the deposit of glacial gravel there is 136 feet in depth.

A deposit 1¼ miles northeast of Emmaus, a glacial kame, is composed mainly of sand and has been extensively worked. Much material has been shipped from this place for use in mortar and for foundry work. About 30 carloads a year were shipped. A section of the deposit is given in the discussion of glacial deposits.

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[*] Pennsylvania Second Geol. Survey, Rept. D3, vol. 1, p. 48, 1883.

Alluvial sand and gravel.—Along Lehigh River alluvial deposits occur at many places, and the islands in the river also are composed of alluvial debris. In most places the alluvium consists of mud in which there is a large admixture of anthracite dust, but in a few places deposits contain much sand and gravel. Below Slatington the alluvial gravels have been dug for ballast in several places. A short distance below Cementon considerable alluvial sand was dug and shipped to Catasauqua and Emmaus foundries for molding purposes. The deposit was about 7 feet in depth.

Sand from mud-dam deposits of limonite iron mines.—In the discussion of ocher a description is given of the character of the deposits in the ponds into which the waste material of the limonite mines was washed. The coarsest sand was deposited near the place where the water entered the pond, and the finer sediment was carried farther out. This sand, which consists of small grains of quartz, quartz crystals, botryoidal chalcedony, thin flakes of limonite, and a few fragments of shale, limestone, and quartzite, is mixed with considerable ocherous clay. Even when the mines were in operation this sand was sometimes used for ordinary plaster and mortar, and since the mines were closed, sand for these uses has been dug from the old deposits that are common throughout the region. In some places several feet of sand comparatively free from clay can be obtained, but in most places layers of clay are so closely interstratified with the sand that clean sand is hard to get. If the material were washed a large quantity of good sand could be procured from almost every mud-dam deposit in the county. Notwithstanding the difference in ocurrence, the sand from the limonite mines in the limestone and that from the mines in the quartzite are strikingly similar.

In working these deposits it is usually necessary to screen the material to remove any large fragments. The sand was sold for 35 to 45 cents a ton at the pit, or 75 to 85 cents delivered.

An unusual sand product is being produced by Walter Seem about half a mile northeast of Old Zionsville. He quarries and grinds Byram gneiss for chicken grit. By means of a jaw crusher, rolls, and screen, the rock is reduced to sizes suitable for poultry.

GRAPHITE

Graphite occurs in several places in the metamorphic gneisses of South Mountain in the southern portion of Lehigh County, but has never been worked with profit. Considerable prospect work has been done in three localities, but so far as known no attempt was ever made to mine and market the graphite.

Vera Cruz Station.—The Backenstoe graphite mine is located about one mile east of Vera Cruz Station and one mile west of Limeport, on the north side of the road connecting the two places. The history of the mine is somewhat indefinite, but information obtained from different sources indicates that it was first opened about the middle of the last century as a gold and pyrite mine. The large amount of pyrite occurring in the graphite ore may possibly contain traces of gold. It is said that many men in the vicinity lost money in the venture.

Between 1890 and 1900 it was reopened as a graphite mine and exploratory work was carried on for about two months. A decade later the property was purchased by the Schuylkill Stone Co. of Philadelphia, and the tunnel was again cleaned out, but no further work done.

The development work consists of a shaft about 35 feet in depth, located near the top of the hill, and an adit about 150 feet in length that extends into the hill at a lower level. There are no exposures of the graphite rock near the mine and the shaft and adit can not be entered. The loose pieces of rock obtained from the adit and shaft, however, probably represent the true character of the rock fairly well.

The rock is a graphitic gneiss composed mainly of kaolinized orthoclase, with some perthite, white quartz, pyrite, graphite, biotite, hornblende, and an asbestiform mineral. Many specimens show a distinct augen or lens structure, the pyrite especially occurring in small lenses about half an inch in diameter, about which the graphite flakes are curved.

The graphite flakes are friable, probably due to weathering, and some of the graphite even appears to be amorphous. Many of the larger flakes are iridescent.

Much of the rock seems to have been sheared and the flakes of graphite overlap, forming streaks of matted graphite flakes extending through the rock. Pegmatites are present and contain large flakes of graphite irregularly disseminated throughout the rock.

Biotite, while relatively abundant in some specimens, is practically absent in most of the rock and would not be a serious handicap. Nothing is known of the thickness and extent of the graphite-bearing bed. It is doubtful whether the mine would yield a good quality of graphite flake.

Emmaus.—On the farm of John Wright, one mile east of Emmaus, on the top of South Mountain, some prospect pits were dug about 1895. No information is now available concerning the amount of work done, the structure of the rock, and the thickness of the graphite-bearing bed No outcrops of the graphite gneiss could be found in the immediate vicinity of the pits.

The rock in which the graphite occurs is an acid gneiss containing both plagioclase and orthoclase, blue quartz, considerable pyrite in small isolated grains, graphite, and biotite. The plagioclase is greenish gray. The gneiss is indistinctly banded and the graphite flakes show little indication of parallel arrangement. In some of the rock the graphite flakes cut into each other. The flakes are of fair size, up to half an inch in diameter, and are tough and bright. Iridescence was observed in some of the flakes. The presence of the biotite is said to have discouraged the men who were engaged in prospecting the property and operations were discontinued.

Across the road to the east, on an adjoining farm, a prospect pit was also dug, but it has now been filled and only a few pieces of the weathered rock remain about the opening. These seem to indicate the presence of similar rock to that occurring on the John Wright farm.

Powder Valley.—A 37-foot prospect shaft for graphite was dug on the farm of John U. Renninger, half a mile west of Powder Valley, about 20 years ago. From the bottom a drift was run to the south to cut the graphite "vein" which dipped to the south about 45°. The graphite occurs in a rotten gneiss associated with much biotite.

Mr. Renninger states that similar rock was prospected on the farm adjoining on the west.

The fact that the graphite mines of Chester County, once extensively worked, have long been idle, as are all the once profitable graphite mines of New York, New Jersey, and Alabama, is sufficient to discourage anyone from attempting to open mines in Lehigh County, where the graphite is of poorer grade and more intimately associated with biotite.

CORUNDUM

Practically all the known facts concerning the corundum locality near Shimerville are given in the chapter on Mineralogy. A very small amount is reported to have been shipped. It is not of commercial importance.

MICA

Mica in small flakes is a prominent constituent in some of the crystalline rocks of South Mountain. All commercial mica is found in pegmatites. Pegmatite dikes occur in many places in the gneisses of Lehigh County, but most of them contain very little mica. A few, however, contain fairly coarse-grained muscovite. One of these dikes, about 1½ miles northwest of Colesville, was prospected in 1883 by the sinking of two shafts. Some crystals were found that produced sheets from 3 to 4 inches in width, but they were not numerous enough to make the project profitable. The muscovite was considerably clouded by included impurities.

QUARTZ-MICA SCHIST ("SOAPSTONE")

In several places in the areas of gneiss there are rocks which contain large amounts of quartz, mica (sericite), and sillimanite. Rock in which the sericite is especially abundant feels "soapy" to the touch, somewhat like talc, and it is locally known as "soapstone." Actually it contains only minute amounts of talc. Under the misapprehension that the rock was soapstone, a quarry was opened in it one mile north of Colesville almost on the Lehigh-Northampton County line. Some of the material was used several years ago for furnace lining by the Bethlehem Steel Co. It is reported to have been satisfactory for this purpose.

GROUND WATER RESOURCES *

Ground water has been utilized in all parts of the county, and yet complete data in regard to its development are not obtainable on account of the long time since the region was first settled. Many of the wells were dug more than 100 years ago, and the present owners or occupants of the land can furnish no information in regard to their depth or material penetrated.

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* Note: The water resources of the region have been previously discussed briefly in the following publications which in part supplement the descriptions given here.

1. Hall, George M., Ground Water in Southeastern Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. W2, 1934.
2. Water Resources Inventory Report of Water Supply Commission of Pennsylvania, Part VI, 1920.

Of the water that falls on the region in the form of rain or snow, part is evaporated, part runs off into the streams at once, and part sinks into the soil. The relative proportion of these three quantities depends upon so many factors, such as the way in which the precipitation occurs, whether in heavy downpours or gentle rain, the temperature at the time of the precipitation, the character of the ground—whether bare or covered with vegetation, whether soft or frozen, whether dry or saturated with water and the slope of the surface, that it is impossible to determine how much of the rainfall disappears into the earth to form the underground water.

Throughout the great limestone belt of Lehigh County where the slopes are gentle, the soil loose through cultivation, and the underlying rocks porous or cavernous, doubtless half or more than half of the annual precipitation finds its way into the underlying rocks. In many places in this belt sink holes are well developed and there are no surface streams. In the regions of shales and gneisses, on the other hand, where the rocks are less soluble, the slopes steeper, and the country less cultivated, the direct run-off probably exceeds the quantity of water passing into the earth.

Part of the water that passes into the ground is drawn to the surface later by capillarity and is evaporated, part is discharged by vegetation, part emerges along the slopes of the hills as seeps or springs, part probably continues its passage to the Lehigh and Delaware rivers by underground channels, and part remains practically stagnant in the rocks. Though some of the deep-seated waters may originate a short distance beyond the confines of the county, it is doubtful whether any large quantity of even the deepest waters has come from distant points. The rainfall of the region thus determines the quantity of underground water available.

There is scarcely a rural home, a community, or an industrial plant in the county that has not at one time or another been concerned with the question of ground water. Resident geologists are more frequently consulted on this problem than on any other subject in their domain and the manipulators of the divining rod, usually the forked stick, have found abundant opportunity to practice their profession. It is not uncommon for both geologists and "water witches" to be consulted on the same project. Residents of the region share the common belief in the greater purity of underground water as compared with surface stream water, a belief that in many portions of the region is well justified because of serious pollution of the streams. Treated stream water by many is used by necessity rather than by choice.

The discussion of the underground water resources of the county is best treated by sections because of the different classes of rocks in different areas. The quality and quantity of water obtainable in each section is largely determined by the kind of rocks in which the water is contained.

The underground water of the region is the source of both well and spring water. In some sections springs are abundant and supply the residents with sufficient water for all purposes. In other sections there are no springs. In a few places difficulties have been experienced in securing well water and the necessary water is obtained from cisterns. In protracted droughts water is hauled in barrels from nearby creeks or wells.

KITTATINNY (BLUE) MOUNTAIN

Inasmuch as there are no residences on Kittatinny (Blue) Mountain there has been no necessity for investigating the underground water resources of that section. However, the time may come when homes may be established there. Beyond the limits of Lehigh County some houses have been built at and near the crest of this mountain.

The mountain is composed of the Shawangunk sandstones and conglomerates. Although these are generally well cemented by silica that fills most of the interstices, there are some fairly pervious beds, besides which the openings between the beds and also numerous joints afford easy circulation of water. Where the crest of the mountain is narrow the water level probably is very deep and only a small supply of water could be obtained except by drilling almost, if not quite, as low as the slate area at the base of the mountain. Where the mountain top is broad a small amount of water might be got by a comparatively shallow well, perhaps enough for household purposes.

Drilling in the Shawangunk is expensive as the rocks are extremely hard where they are not decomposed by weathering. A local well driller in an adjoining county failed to realize this condition to his sorrow when he took a contract to drill for water in this formation.

Springs occur along the foot of the mountain but they are generally concealed by thick talus deposits and their presence is determined by marshy conditions or by seepages when excavations are made in the talus.

Because of the relatively insoluble character of the Shawangunk rocks, any water obtained from them is low in mineral matter.

MARTINSBURG SLATE REGION

The slates of the northern part of the county permit the rain water to pass quickly through the surficial soil and weathered slate but very slowly through the compact, fresh, fine-grained rock beneath. Percolation through the slate itself does take place but most of the water that goes far below the surface moves through openings of joints and along loose bedding planes and possibly along cleavage planes. These openings are very narrow and are not widened by solution, as in the limestone region, because of the relative insolubility of the slate. The result is a very slow downward movement of the rain water and the almost complete absence of large underground streams. Where faults are present the water tends to follow them.

The water from the Martinsburg is almost everywhere of good quality if not contaminated by surface pollution. However, there are several places where both spring and well waters have enough sulphur to make the water undesirable or useless. The sulphur in the water is derived from pyrite, which in some places occurs in the slates in considerable abundance. In the slate quarries cubes of pyrite are frequently noted, especially in the more highly carbonaceous beds.

The conditions in the Martinsburg favor the issuance of water from the slopes as springs and militate against large supplies of water being obtained from wells. Springs are more abundant in the Martinsburg slate belt than in any other part of the county. Springs occur in almost every valley in the region, both large and small. Northward-flowing streams have fewer springs. If the water does not emerge in a well-defined spring it may issue in a line of seepage. Some farmers dig a catchment basin in a seepage area and obtain sufficient water for household and farm purposes.

In general the springs of the Martinsburg belt do not furnish a large supply of water but generally enough for farm uses. Many of them are permanent and can be depended upon at all times, but many more flow only during the winter and spring. During prolonged droughts some disappear. Others cease to flow for no obvious reason but probably owing to the blockage of the channels or the opening elsewhere of easier passage. The general permanence of these springs accounts for so few of the streams of the region bcoming dry during the late summer and early fall.

The temperature of the water issuing from the springs is sufficiently high even during the extremes of winter to prevent freezing. During the winter of 1937-1938 several springs were examined at intervals. Most of them remained at 51° F.; a few changed from 53° F. to 47° F. during cold periods.

Even though springs are abundant in the slate region, they cannot supply all the residents, and wells must furnish much of the water needed. Hundreds of wells have been dug or drilled. Most of them are less than 100 feet deep. Many wells only twenty feet deep furnish enough water for farm use. In general it is necessary to go deeper on the uplands close to the deep narrow valleys than farther back on the divides. Wells yield a fairly steady supply of water but not in large quantity. The water comes in slowly. One concern desiring a large supply, dug several shallow wells of large diameter.

All the old wells were dug by hand but almost all those put down during the last twenty years are drilled wells. These are generally deeper, many average over 200 feet in depth. These deeper ones are apt to secure water under artesian pressure that will rise far above the place encountered and in some instances will flow.

LIMESTONE REGIONS

In those portions of Lehigh County underlain by the Cambrian and Ordovician limestones the water problem is serious in many cases.

Ground water in limestone regions flows mainly in well-defined open channels formed by solution along ordinary joints or bedding planes, and the surface water passes into these underground channels. As the water in the limestones is concentrated in definite channels, one of these channels must be struck to obtain water in quantity, and the uncertainty of finding one of them has favored "water witching," which is still practiced in many regions, although repeatedly shown to have no scientific basis and to be entirely unreliable.

Some water is usually obtained at the contact between the loose residual and glacial loamy clay and the underlying compact limestone. Many wells fifteen to thirty feet deep draw their supply from this horizon and obtain sufficient water for domestic use except in times of drought. The water in such wells is, however, easily polluted by surface drainage, and these wells are gradually being abandoned. In place of the abandoned shallow wells deep wells are sunk; if these are not successful, cisterns are used. Some farmers depend entirely on cisterns for household water. This water is soft and greatly preferred for certain purposes.

Many deep wells have been bored in the limestones during the last few years, and most of them have been successful. One experienced driller states that he has obtained fair supplies of water at depths of about 200 feet in about 70 percent of the wells he drilled in the limestones of this section. As shown in the table, some wells procure very large supplies, a few of them from several different horizons, yet a hole may be sunk within a few feet of a strong well and still be dry on account of the impervious character of the solid limestone. For this reason, dry wells before being abandoned should be dynamited in order to shatter the surrounding rocks. As the rocks in this region have been greatly broken by folding and faulting, water may be obtained more readily from these limestones than from those in other regions that have been less subjected to stresses.

The water in most of the deep wells rises above the level at which it is struck, and it overflows from numerous wells. In general the deep wells obtain water under the greatest pressure, but, due to marked irregularity, locations where flowing wells can be obtained cannot be predicted.

Many springs occur in the limestone areas. Some of them are unusually strong, being underground streams that rise to the surface under artesian pressure. Some are important sources of municipal water supply. The most important are Schantz Spring and Crystal Spring, both of which are described under the discussion of the Allentown municipal water supply. Several other springs in the limestone regions have become famous on account of the large volume of water which they yield.

Calypso Spring. An island in the Lehigh River at Bethlehem named Calypso (or Catalpa) was long a favorite pleasure resort. It has disappeared, partially by excavation but mainly by the filling of the south channel of the river. Near its eastern end there was a large spring that was praised both by residents and visitors for its unfailing supply of pure water. The water probably emerged along a fault plane. One may well wonder whether the water was as pure as claimed.

Oppelt's Hydropathic Institute. In 1846 Franz Heinrich Oppelt acquired a few acres of land in Fountain Hill and erected buildings where St. Luke's Hospital is now located, as a sanitarium and summer resort. It was named Oppelt's Hydropathic Institute but commonly called the Water-Cure. It was operated until 1871 and became locally famous. He used the water from some springs at the foot of the steep slope. The treatment is said to have been a liberal use of hot and cold water both internally and externally. The spring water, which apparently came from a fault between the gneiss and limestone or between the gneiss and sandstone, was evidently pure both chemically and bacteriologically.

Helfrich Spring. At the sharp loop in Jordan Creek a short distance north of Allentown there are several springs. The largest of these, on the west side of the highway, is now known as the Helfrich Spring. At different times in the past it was called Grim Spring and Blank Spring. The water emerging from the shattered limestones in several places supplies fish ponds.

Menges Spring. About three-fourths mile northwest of Mountainville is a large limestone spring commonly known as Menges Spring.

Big Spring, Trexlertown. A large spring a short distance west of Trexlertown has long been famous. Theophile Casenove noted it in the journal of his travels in 1794. He says: "At Trexler's Tavern 5 miles; bad lodging; isolated on the road; ½ mile from there you pass near Big Spring. It is such a rich and steady spring that it gives enough water to set a mill going 200 feet away." (Translation by R. W. Kelsey, 1922.)

Other Springs. In the Saucon Valley there are numerous springs, some of which are in the limestones some distance from the bounding hills of gneiss, but most of which are at or near the fault contact of the gneiss and the limestones. The former are mainly of large size and seem to be the emergence of well developed underground streams. The latter generally furnish less water, but they are mainly permanent and the water is excellent and sufficient for domestic use. Much of the water comes from the relatively insoluble gneisses and hence is low in dissolved mineral matter. Water originating in the limestones is generally hard.

In many places there are faults of considerable displacement at the foot of the gneiss hills. North of Lanark this displacement is approximately 4,000 feet. Lines of seepage or well-defined springs are abundant along these fault planes and many homes obtain their water from springs along the lower slope of these hills or from shallow wells dug in the talus. From them the water flows by gravity into the houses and barns. So common are these occurrences that one is justified in recommending search for good quality spring water in all such places in the county, although it should be borne in mind that this is by no means a universal situation.

The springs of the limestone region are affected by drought, and many disappear in summer, though the larger ones have never been known to fail entirely.

All the ground water of the limestone areas is hard because of the mineral matter it dissolves in passing through the soluble rocks. The amount of material in solution ranges within wide limits owing to the differences in distance through which the water has flowed, the length of time it has remained in contact with the rocks, and the relative solubility of the inclosing limestones. This water causes the formation of much scale in boilers. In drinking water the mineral matter, mainly calcium and magnesium bicarbonates, is not regarded as detrimental.

The limestone waters are subject to contamination, as the areas are thickly settled and surface waters in many places find ready access to underground channels. Limestone waters near cities and towns, whether from wells or from springs, should be treated on account of the sewage that is continually poured into the underground channels, and should be examined bacteriologically from time to time to ascertain the extent of contamination. If wells are tightly cased for some distance into the solid rock the danger of surface contamination is lessened, but it is not entirely removed, as polluted waters may reach great depths through open fissures with practically no filtration. Doubtless a complete sanitary survey of the region would demonstrate that many of the sources are too badly polluted for safe use.

By experience it has been found that the best surface indications of underground streams in the limestone of this region are sink holes into which the surface water flows to unite with underground streams. Boring in the vicinity of sink holes or in the line of a series of sink holes is reasonably certain to encounter water. In some places the water is present in enormous quantities. Surface depressions that are not entirely closed are also favorable indications. Large supplies of ground water can generally be obtained in the vicinity of limonite iron ore mines or deposits. Scarcely an iron mine in the entire region was worked to a depth of fifty feet without encountering water and at greater depths the amount became so great as to cause certain mines to be abandoned. There is a close connection between the iron ores and ground water in that the ore deposits were concentrated and deposited in those places where there was free circulation of ground water. The same sort of circulation and ore formation still continues.

In certain places the limestones have been unduly shattered as a result of complex folding and faulting. If such places can be located for drilling sites abundant water can be assured. Drilling is difficult in such places as the hole is apt to become crooked and the drill may stick.

In these limestone regions there is no recognized aquifer. Even though there were some bed or series of beds with greater permeability so that the water would be yielded more readily, the complexity of structure would prevent one from predicting the depth at which it would be encountered.

From what precedes it also should occasion no surprise when one well or several obtain plenty of water at 100 to 200 feet and on an adjoining property a well twice as deep furnishes little water.

The numerous veins of calcite and quartz in the various limestones, particularly noticeable in the Jacksonburg cement rock, furnish abundant evidence of the free circulation of ground water through these rocks in past geologic ages.

In the limestone areas, well drillers frequently encounter cavities where the drill drops a few feet. These are underground solution caverns. Some of these cavities are filled with sand and gravel that has come from the surface.

In northeast Catasauqua almost on the county line, the borough of Catasauqua drilled two holes, one 212 feet deep, in clay, sand, gravel and iron ore, without striking bedrock. Dolomitic limestone crops out only a short distance away, so it seems that a deep solution pocket was encountered.

In those limestone regions where the strata have been deeply shattered by complicated folding and faulting and sink holes are both numerous and deep, the water obtained from new wells may contain much fine clay matter in suspension. For example, in the Saucon Valley deep drilling has shown that the rocks are shattered and cavernous to the depth of approximately 400 feet. Some of the wells yield murky water for a considerable time, so long that the owners become skeptical of clear water ever being secured. However, eventually the clay filling the openings through which the water circulates is washed away and the water clears.

CAMBRIAN SANDSTONES

The band of sandstones and quartzites along the sides of the South Mountain has been prospected for water in few places, mainly on account of the narrowness of its outcrop. The quantity of water encountered in the operation of the limonite iron mines in this belt of rocks in a few places proves that these sandstones and quartzites contain much water. The water passes along joints and bedding planes or through the rocks themselves and is seldom concentrated in definite streams, except in places where the rocks have been broken and displaced by earth movements. The best place to procure water is at the contact between these rocks and the underlying gneisses.

Wells in these rocks should be sunk a short distance away from where they disappear beneath the limestones. As the rocks near the mountain almost invariably dip steeply, the sandstones or quartzites are within a short distance carried beyond the depth at which they are available as sources of water. Springs are not numerous in these rocks, but there are some in places where the rocks have been shattered.

The water from the Cambrian quartzites and sandstones is low in mineral content because of the insoluble character of the rocks with which it comes into contact, and it is uncontaminated because the slopes of the mountain are sparsely settled.

CRYSTALLINE ROCKS

Until recently there has been little demand for underground water in that portion of the county underlain by the crystalline rocks of South Mountain as there were few residences and no industries requiring large quantities of water. With improved roads and the year-round use of automobiles many homes have been built in these elevated areas.

The springs at the base of these hills have already been described. A surprisingly large number of springs emerge on the upper slopes and almost at the summits, probably from fault or fractured zones.

The Lechauweki Springs, on the north slope of the hill a short distance east of the Children's Home, Fountain Hill, were at one time better known than now. The water comes to the surface along a fault plane of a few hundred feet displacement. Coming from the gneiss, the water is soft.

At one time a resort hotel with 120 rooms was erected here. An advertising leaflet issued in the spring of 1875 contained the following:

"The Lechauwcki Springs is a summer resort that offers special attractions to those desiring rest, comfort and true enjoyment, without the empty show and tiresome exactions of our modern watering places. * * * The springs furnish enough of the coolest crystal water to supply the wants of a thousand people. * * * There are three large trout ponds arranged *en echelon,* and the water, after passing through them, forms a miniature cascade and empties into a lake whose pellucid waters and quiet beauty are delightful to look upon, and in the center of which is a beautiful arbor."

The Lechauwecki Spring Water Co. at present owns the springs and supplies about 50 consumers in the vicinity. In January 1940 the water in the reservoir froze and it was necessary to obtain water from the Bethlehem City Water Co. for a time.

About one-fourth mile east of Sigmund in Upper Milford Township a large spring emerges at a fault contact between the gneiss of Furnace Hill and the Hardyston sandstone. A reservoir has been built and the water piped to the borough of Red Hill, Berks County.

Springs in Leiberts Gap also furnish water from fault planes within the gneiss.

Near the surface most of the crystalline rocks have been decomposed by weathering to such an extent that they will readily permit the downward percolation of rain water. The depth of this layer of rotten rock varies greatly. It may be as much as 100 feet. Below this the movement of water is through narrow joint planes or faults and these decrease downward both in size and number. Numerous wells from 25 to 100 feet in depth in the gneiss obtain enough water for household use whereas others were practically dry.

At Summit Lawn the residents generally obtain sufficient water by digging wells 25 to 30 feet deep. Most drilled wells, 80 to 90 feet in depth, obtain ample supplies. The water is soft.

Half of the deep wells that have been bored have been failures. If water is not obtained within 200 feet it is generally regarded as useless to continue to lower levels. A few excellent wells have been obtained in the gneisses but most of them yield only small quantities.

The water in the gneiss contains little dissolved mineral matter, and when it is protected from local pollution it is very desirable. In a few places where pyrite is an abundant constituent of the gneisses the water may contain iron.

The author has been asked frequently about the probability of obtaining water from wells on the crest of some of the gneiss hills inasmuch as "water witches" have stated that good supplies could be obtained. The chances of getting more than that coming from surface seepage in wet weather are remote unless a fault plane is encountered and that at considerable depth.

TRIASSIC ROCKS

The red shales, sandstones, and conglomerates of the Triassic in the southeastern portions of Lower Milford and Upper Saucon townships contain sufficient ground water for domestic purposes. Almost every well will yield some water, as ground waters percolate through the joints and between the beds of shales or through the fine to coarse grained sandstones and conglomerates. In a general way, the deeper the well the more extensive is the gathering ground and consequently the greater is the yield. Some wells 25 to 50 feet deep may furnish sufficient water for a single household, but in other places it may be necessary to drill to a depth of 150 to 200 feet. The water obtained is almost uniformly low in dissolved mineral matter.

The diabase in this region is too limited in extent and too dense to be of any importance as a source for underground water.

RESIDUAL, ALLUVIAL, AND GLACIAL DEPOSITS

The residual deposits of the different kinds of rocks are generally sufficiently porous to permit passage of underground water. In low-lying regions where the ground-water level lies close to the surface and the residual rock deposit is 20 feet or more in thickness, shallow wells may obtain considerable water from this source.

The glacial deposits consisting of sands, cobbles, and clays are generally too thin to hold much water. However, in a few places, such as the morainal deposits between Wescosville and Trexlertown and in Hanover Township, they may be up to 50 feet in thickness and shallow wells sunk here obtain considerable water.

The alluvial deposits in the Lehigh River lowlands and along some of the tributary streams range in thickness up to 40 feet. Even during periods of extreme drought the ground-water level rarely sinks to that depth along the streams so that wells sunk through the porous unconsolidated alluvium seldom fail. The Trojan Powder Co. has obtained a large amount of water from such wells near Jordan Creek even when the creek bed is dry for considerable distances both up and down stream.

MUNICIPAL WATER SUPPLIES

The boroughs and towns of Lehigh County are mainly supplied by water companies, some under municipal ownership and others privately owned. Each community has its individual problems and seeks a supply from near-by available resources. Most of the urban population is close to the Lehigh River and therefore logically it should be considered as the source of supply. However, the serious contamination by the refuse from the washeries of the anthracite region and the sewage and waste waters of residences and industrial plants render the water unsatisfactory. Nevertheless necessity has compelled its use in some instances. Bethlehem has long been forced to use river water in part, but developments described below will shortly obviate this situation. Of course polluted water can be and is rendered sanitary by chlorine treatment, but this is everywhere considered undesirable.

Plans for a large supply of surface stream water, sufficient for practically all the towns of the Lehigh Valley, have long been considered but combined action has not resulted. Streams in a thinly inhabited section of the Pocono Mountains might yield sufficient water of excellent quality for all the communities from Slatington to Easton.

Allentown. The early residents of Allentown obtained their water supplies from springs near the base of the bluffs bordering the Jordan and Little Lehigh creeks and from private and public wells.

The first water company supplying the major portion of the settlement was the Northampton Water Co. (later changed to Allentown Water Co.), which began operations in 1831. The source of supply was Crystal Spring (also known as Worman Spring and Silver Spring) located at the foot of the limestone bluff close to Little Lehigh Creek almost a mile above its junction with the Lehigh River. This spring has a reported average daily flow of 4,000,000 gallons.

In 1869 the city purchased the water company. Crystal Spring furnished the entire supply until 1898, when the City Council purchased the Schantz Spring about 4 miles west of the city. This spring has a rated average flow of 8,000,000 gallons daily. When necessary, an additional supply of water can be obtained from Little Lehigh Creek.

Inasmuch as all the water comes from the limestone region, it is hard and also liable to contamination, but is treated and carefully watched. The two springs are the result of emergence of large underground streams. The water falling on the surface readily finds its way into the cavernous limestones and establishes major streams and tributaries similar in many respects to surface stream drainage.

Many curious explanations have been offered to account for the large volume of water of Schantz Spring. The following quotation is typical:

> In this marvelous spring, which is supposed to be connected by a subterranean channel with Lake Erie, the water pours from an opening three feet in diameter and apparently bottomless. (Hauser, 1906.)

It is scarcely necessary to say that such a belief is groundless and does not merit the presentation of evidence in disproof.

Bethlehem. Inasmuch as the major portion of Bethlehem lies in Northampton County and its water supplies have been discussed in the volume devoted to that county, it is inadvisable to repeat the descriptions.

West Bethlehem and Fountain Hill lie within Lehigh County, but are supplied with water by the municipally-owned Bethlehem Water Co. At present, part of the water supply comes from wells and from Lehigh River near the pumping plant, which is located west of the city and within Lehigh County. Before the appearance of this volume it is expected that all of Bethlehem and most of Fountain Hill will be supplied with water from Wild Creek, north of Kittatinny (Blue) Mountain.

For many years certain residences in Fountain Hill were supplied with spring water from the lower slopes of the gneiss hills or from the fault that brings the gneiss in contact with the limestone.

In 1866 Tinsley Jeter built a small reservoir to collect the water from several springs near the old Bishopthorpe school. Pipes were laid to supply residents as far as Union Station. In 1872 Dr. G. B. Linderman formed the Cold Spring Water Co. to collect water in a similar way from springs on property which he owned. Several homes on Delaware Avenue and Huron Street were supplied.

Catasauqua. The water supply of Catasauqua is furnished by the municipally-owned water plant with the exception of North Catasauqua and West Catasauqua, which are supplied by the Clear Springs Water Co. The water comes from three wells slightly more than 200 feet deep. They are drilled in cavernous limestone and yield from 400 to 600 gallons a minute. The water is hard. An attempt to obtain water from a new well a short distance from the former wells and pumping plant encountered a deep pocket of clay and failed to find any rock to the depth of 100 feet. A new location was selected.

Coopersburg. Several springs and seepages southeast and east of Coopersburg have furnished sufficient water for a few homes. The municipal water works obtain their principal water supply from several springs located about two miles east of the borough in Bucks County and from wells near-by. A borough-owned well in the southeast part of Coopersburg 300 feet deep has yielded 144,000 gallons daily.

All of the water supply comes from the Triassic red shales and sandstone. As these rocks are relatively insoluble, the water contains a relatively small amount of dissolved mineral matter.

Emerald and Slatedale. In 1908 the Washington Water Supply Co. constructed a 13,000,000-gallon reservoir at the base of Kittatinny (Blue) Mountain below Bake Oven Knob to impound the water from several springs at the head of Trout Creek. The company supplies water to the residents of Slatedale and Emerald (Franklin). The supply is ample and the water is soft. The mains extend to the west border of Slatington.

Emmaus. For several years the borough of Emmaus obtained its water supply from springs and from adits driven into the slope of South Mountain. The location is almost exactly on the line separating Upper Milford and Salisbury Townships. The seepage water entering the excavation from the decomposed gneiss and Hardyston sandstone was of excellent quality, but limited in amount. A branch gallery increased the supply somewhat.

In 1909 it was found necessary to get more water, so a well was drilled near the adits. When the drilling reached the depth of 700 feet and was in hard dense gneiss with practically no water the well was abandoned on the advice of the writer.

Later a well was put down in the limestone near the railroad and pumping station and a sufficient quantity of water obtained. The water is hard and must be carefully watched on account of the dangers of pollution.

Springs on the mountain side in Upper Milford Township have long supplied water to a limited number of residences in Emmaus.

Macungie. In 1895 the borough of Macungie built a reservoir on the side of the mountain south of the village to impound the water from some springs. The water runs through the mains by gravity and is soft.

Slatington. Slatington obtained its water supply from the Remaly and Kern springs south of the village from 1853 to 1883. The supply becoming inadequate, a new source was sought to the northwest along the lower slopes of Kittatinny (Blue) Mountain. Two reservoirs of

240,000 and 260,000 gallons capacity have been constructed to catch the water coming from springs. The water is soft. The borough owns the springs and operates the plant.

Other communities. Cementon, Egypt, Coplay, West Coplay, West Catasauqua, North Catasauqua, Hokendauqua and Fullerton in Lehigh County and Northampton in Northampton County are supplied by the Clear Springs Water Co. The main supply comes from Spring Creek, but is supplemented by water from the Lehigh River. The company is the continuation of the water plant of the Crane Iron Works started in 1839. It was sold to the present concern in 1905. The water is fairly soft.

Individual Wells

As discussed on preceding pages, the occurrence of underground water varies in the different kinds of rocks. The presentation of selected individual well records therefore may be misleading. Furthermore, complete records have been kept of few wells and the yield of each well changes due to changes in the level of the water table and other causes. Nevertheless, records are given. Many other similar records might be obtained from well drillers and owners of properties.

No differences are recognized in the ground-water conditions in the different formations of each type of rock, but conditions are different in each type. So far as known the ground-water conditions are the same in the Tomstown, Allentown, and Beekmantown limestones, they are of another kind in the Byram, Moravian Heights, and Pochuck crystalline rocks, and still different in the Martinsburg shales and slates.

Analyses of well water, although available, are not offered because of the variations that occur in the water under different conditions, such as varying rainfall, rate of pumping, methods of analysis, and methods of reporting results. Chemical analyses are important only for a specific time or a specific purpose.

Wells of Lehigh County

Owner	Location	Depth feet	Depth to water level	Yield gal. a min.
	Martinsburg shale			
Lehigh Community Park	1¼ miles northeast of Fogelsville	145		25
Lehigh Community Park	1¼ miles northeast of Fogelsville	350	110	100
Fred Sterner	Huckleberry Ridge	366	185	10
Trexler Game Preserve, CCC Camp		500	85	4
Knerr Sisters	West of Trexler Game Preserve	330	20	4
	Limestones			
Saucon Valley Country Club	Saucon Valley	200		
Gross Estate	Saucon Valley	162		40
Gross Estate	Saucon Valley	143		
Gross Estate	Saucon Valley	148		40
Schick Farm	Saucon Valley	225	220	
C. A. Buck	Saucon Valley	200	7	15
Borough of Emmaus	Northeast of Emmaus	260		125
Borough of Emmaus	Northeast of Emmaus	325		200

Wells of Lehigh County

Owner	Location	Depth feet	Depth to water level	Yield gal. a min.
Emmaus Silk Co.	Emmaus	125	70	50
H. Kostenbader Brewing Co.	Emmaus	270		?
Rodale Mfg. Co.	Emmaus	295	125	35
Morris Safier	Alton Park, north of Emmaus	122	80	10
A. H. S. Cantlin	S. W. of Allentown	185	75	10
United Materials Co.	S. W. Allentown	70	15	100+
Helen Wieda	East of Trexler Fishery	150	90	10
George Mosser	1½ miles west of Trexlertown	140	90	15
Robert Mertz Hotel	Wescosville	133		10
Lehigh Portland Cement Co.	Fogelsville	265		800
Lehigh Portland Cement Co.	Fogelsville	350		1000
Charles Kuhns	½ mile south of East Texas	60	8	15
Robert Bright	Spring Creek near Trexlertown	155	20	10
Fegley	Trexlertown	223	15	10
Wm. Diebert	Near Minesite	160	100	10
Dr. C. G. Maulfair	Near Minesite	167	70	10
Wm. Knittle	South of Macungie	224	115	5
Edwin Koch	Mountainville	150		20
Salisbury School	Mountainville	153	30	15
Allen Hagenbuch	2 miles southwest of Allentown	140		15
Keystone Textile Co.	South Allentown	255	45	40
Stuyvesant Silk Mill	South Allentown	200	60	40
City of Allentown	South Allentown	225		225
Dr. Martin Kleckner	South of Cedar Crest Colliery	175	60	15+
C. H. Ziegenfuss	Southwest Allentown	58	8	300
Dr. Paul Rainer	Cetronia	135	70	15
Ira Werley	Farmington	300	130	15
Avondale Farms Dairy Co.	Bethlehem	500	flows	200
Lehigh & New England Cold Storage Co.	West Bethlehem	365		100
A. G. Newhard Ice Co.	East Allentown	300	120	100
Harry Davis	Near Shoenersville	178	100	10
Sylvanus Peters	Shoenersville	157	115	15
M. P. Schantz	½ mile northwest of Allentown	270	110	15
Jordan Silk Dyeing Co.	North Allentown	100	25	100
Arbogast-Bastian Co.	Allentown	708		350
L. F. Grammes & Sons	Allentown	404	20	70
Brey and Krause Co.	Allentown	100	40	50
Boat and Swimming Club, Adam Island	Allentown	110	15	40
Neuweiler Brewing Co.	Allentown	407	12	200
Allentown Merchants Ice. Co.	Allentown	324	12	150
Allentown Tire and Rubber Co.	East Allentown	202	35	100
National Silk Dyeing Co.	East Allentown	125	25	40
Jordan Lutheran Church	Walberts	282	30	10
John Jaindl	Wennersville	156		15
Wm. Trinkle	Northwest of Allentown	175	90	10
Alvin Butz	Chapman	220	100	10
McBride Brothers	Fullerton	300	135	50
Fuller Engineering Co.	Fullerton	200	175	300
Mrs. Andrew Yeager	North Allentown	160	50	10
Wm. J. Weber	North of Allentown	157	90	15+
Oscar Henninger	1 mile west of Fullerton	125	30	12
John Nylander	½ mile west of West Catasauqua	130	90	15
C. L. Lehnert Brewing Co.	Catasauqua	204	80	80
A. F. Kostenbader	Catasauqua	205		150
Crystal Ice Co.	Catasauqua	107	18	150
Ray Benninger	Sherersville	60	35	10
Victor Fry	Sherersville	111		10
Victor Fry	Sherersville	95		10
Roy Rinker	Mechanicsville, N. E.	169	25	15
Trojan Powder Co.	½ mile northeast of Jordan Bridge	500	160	100
William Geschwint	Seiple's Station	220	130	10
Arlington Memorial Park	Mickleys	170	75	15
Lehigh Portland Cement Co.	Ormrod	173		100
	Hardyston sandstone			
Wm. Rowe	South of Mountainville	295		6
Woodrow Gangewere	East of Mountainville	145	110	10
Ambos, Eleanor	Macungie-Shimerville Road	175	40	15
Ambos, Eleanor	Macungie-Shimerville Road	125	35	15
Richard Steckel	Macungie-Shimerville Road	225	30	5
Mrs. Janette Raymond	Southeast of Macungie	194	120	10
Sacred Heart Sanatorium	Limeport	350	130	40

Wells of Lehigh County

Owner	Location	Depth feet	Depth to water level	Yield gal. a min.
	Triassic shales and sandstones			
D. P. Reynolds	Top of Flint Hill	115	55	8
F. B. Nothstein	South of Center Valley	80	10	10+
James Bishoff	½ mile west of Coopersburg	75	22	10
Jos. Illick	West of Coopersburg	85	17	10
Jos. Illick	West of Coopersburg	90	34	10
James Bender	South of Limeport	200	15	20
George Hausman	South of Limeport	250	35	25
	Crystalline rocks			
Borough of Emmaus	¼ mile east of Emmaus	700		small
Mountain Water Co.	¼ mile south of Emmaus	200		35
R. P. Stevens	Summit Lawn	94	45	50
Laura Kuntz	Summit Lawn	186	25	50
Charles Yaeger	Summit Lawn	145	30	20
Security Realty Co.	1¼ miles southeast of Mountainville	165		7
Children's Home	Fountain Hill	245		small
J. Reisinger	Farmington	200		5
E. F. Miller	South Allentown	268		30
Allentown State Hospital	East Allentown	770	90	35
Allentown State Hospital	East Allentown	700	90	50
Allentown State Hospital	East Allentown	270	90	80
Allentown Foundry Hardware Co.	East Allentown	220		4
Allentown Foundry Hardware Co.	East Allentown	120		7
H. V. Anderson	South of Gauffs Hill	100	28	3
Benjamin Snavely	South of Gauffs Hill	120	75	10
Sydney Brown	South of Gauffs Hill	139	80	20
Frank Berghold	East of Seiders School House	248	30	2
M. H. Kauffman	Near Shimersville	199	45	20
A. J. Dennis	Southwest of Zionsville	105	60	8
Dr. Buehler	2 miles west of Shimersville	50	25	15

SOILS

The soils of Lehigh County constitute its most valuable mineral asset. Although manufacturing industries generally receive major attention, agriculture contributes largely to the welfare of all the residents.

As the kind of soil usually is very closely connected with the character of the underlying rock, a geologic map may indicate fairly well the distribution of the various types of soils. However, there are exceptions in that soils of the same sort may develop from several different geologic formations. For example, the soil expert does not differentiate between the residual soils of the Tomstown, Allentown and Beekmantown formations nor between the soils of the various kinds of gneisses. On the other hand, a single geologic formation may give rise to more than one kind of soil. Nevertheless, a person familiar with the rock formations can generally predict the character of the surface soil, especially if he takes into consideration the topographic features and the agents of transportation at work in the region.

In a report[1] of the Bureau of Soils of the U. S. Department of Agriculture the soils of Lehigh County are described. Portions of this report are quoted inasmuch as the Government publication is not readily available to many persons. It seems inadvisable to reproduce the soil map showing the exact distribution of the various soil types.

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[1] Carter, Jr., William T. and Kerr, J. A., Soil Survey of Lehigh County, Pennsylvania: Field Operations of the Bureau of Soils, 1912, 53 pp. and map, Washington, 1914.

The following table gives the actual and relative extent of the several soil types mapped in Lehigh County:

Areas of different soils

Soils	Acres	Percent
Berks shale loam	78,976	35.9
Hagerstown loam	47,360	26.5
Gravelly phase	10,880	
Chester stony loam	15,552	7.1
Huntington silt loam	8,576	3.9
Chester loam	8,448	3.8
Dekalb stony loam	8,192	3.7
Rough stony land	5,888	2.7
Hagerstown silt loam	3,840	1.7
Dekalb loam	3,520	1.6
Penn gravelly loam	3,392	1.5
Murrill loam	2,752	1.3
Wheeling silt loam	2,688	1.2
Berks silt loam	2,688	1.2
Lickdale clay loam	2,432	1.1
Berks stony loam	2,304	1.0
Penn shale loam	2,240	1.0
Montalto stony loam	1,216	.6
Penn stony loam	1,152	.5
Schuylkill fine sandy loam	1,152	.5
Holston gravelly loam	1,024	.5
Lansdale silt loam	896	.0
Wheeling gravelly loam	832	.4
Holston silt loam	832	.4
Montalto clay loam	768	.4
Hagerstown stony loam	640	.3
Penn silt loam	384	.2
Lehigh shale loam	384	.2
Wheeling loam	320	.1
Lansdale stony loam	320	.1
Upshur shale loam	256	.1
Mine dump	256	.1
Total	220,160	----

Berks Shale Loam

The Berks shale loam is the most widely distributed soil type of Lehigh County. It is practically coextensive with the Martinsburg shale (or slate) formation and is present in all the northern townships of the county. This soil is the residual weathering product of the shale. The area of this soil is locally called gravel land.

The soil of the Berks shale loam is a light-brown to yellowish-brown silt loam about 8 inches deep. The subsoil is a yellow silty clay loam which grades downward into a yellow friable silty clay. Large quantities of shale or weathered slate chips, with some fragments several inches in width, are scattered over the surface and disseminated throughout the soil section. The shale fragments are soft and easily broken, and where cultivation has been carried on for many years they have been reduced to small particles. A mass of weathered shale is generally encountered within 24 inches of the surface. On some of the slopes this shaly layer occurs at a depth of 8 or 12 inches, while in the comparatively inextensive level areas it may not be reached at less than 30 to 36 inches. The weathered fragments vary from yellow or grayish yellow to olive or brown, while the less weathered fragments of the substratum are more bluish-black in color.

The Berks shale loam naturally has a good tilth, and can be worked easily even when quite wet. The small shale fragments give the soil a loose, friable structure, and enable it to warm up early in the spring.

The topography is rolling to hilly. The configuration of the surface is rounded, the slopes being regular and smooth instead of gullied and rough. The series of rounded, smooth hills give the surface a billowy appearance. In the northern part of the county the type occupies long, smooth ridges, which parallel the Blue Mountain to the north. The hills and ridges reach an elevation of 600 to 900 feet above sea level, and are 50 to 200 feet higher than the intervening valleys.

The drainage throughout the type is good. Owing to the slope, water does not stand on the surface, while the shale fragments in the soil and subsoil permit the rapid percolation of soil water. Where the subsoil is a mass of shale fragments, as it is throughout a large part of the type, the soil is droughty, and crops suffer during dry seasons. Where the shale has weathered more deeply the droughty nature of the soil is less marked. With moderate care the surface does not erode badly and few of the farms include gullied slopes. This is doubtless due to the fact that the mass of small shale fragments keeps the soil from washing badly, except under very adverse conditions.

A large part of this type is in cultivation, though many small areas are still forested with the original growth of oak and other native trees. In the timbered areas the surface soil has a more yellowish color, but after cultivation it becomes darker.

The type is well adapted to general farming, and during favorable seasons good yields are secured. In very dry seasons the yields are low. Consequently crop yields vary considerably, depending on the rainfall. The productiveness of the soil depends largely on its depth. On the steep slopes and tops of the sharper ridges, where the shale mass is near the surface, the crop yields are much lower and less certain than on the gentler slopes and gently rolling tops of broad ridges, where the soil is deeper. While average crop yields are lower than on the Hagerstown soils, under favorable conditions of rainfall and by the use of manure and commercial fertilizers, almost as good results may be obtained. The land is easily cultivated under all conditions of moisture, and since it warms up quickly and responds readily to good treatment, it is considered desirable land. The farm improvements and buildings indicate a general condition of prosperity.

The general farm crops are grown on this soil, though a specialty is made of producing Irish potatoes, to which the soil is particularly adapted. Individual plantings of this crop range from a few acres to 40 or 50 acres. The potatoes are grown largely in conjunction with other general crops. By the liberal use of stable manure and commercial fertilizers, 200 to 250 bushels per acre of potatoes of excellent quality are produced.[1] Some farmers, however, do not use commercial fertilizer, but get good results with applications of barnyard manure. Corn produces 20 to 70 bushels, wheat 15 to 30 bushels, oats 20 to 50 bushels, rye 15 to 25 bushels, and hay 1 ton to 1½ tons per acre. Oats do well only on the deeper phases of the soil in good seasons. In dry seasons, in areas where the shale is near the surface, the yield is very light. There are some excellent fields of alfalfa on the type. About three cuttings per year are secured, with a yield of one-half ton to a ton per cutting. Some buckwheat is grown, with fair results.

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[1] Since the above was published the potato yield has materially increased so that yields of 400 bushels to the acre are not uncommon. Also at present rye is grown to a small extent on the steeper slopes.

On many of the higher ridges (such as Shochary Ridge) irregular and flat sandstone fragments a few inches across are often encountered on the surface and throughout the soil section. Where present in quantities sufficiently large to interfere with cultivation the soil is mapped as the Berks stony loam. In some places numerous fragments of quartz are found on the surface.

Berks Silt Loam

Fine-grained soil on the lower slopes and bottom land in the Martinsburg slate region is classified as the Berks silt loam. This soil is well represented in the vicinity of Slatington, Slatedale, Jordan Valley, Lochland, and New Tripoli.

The surface soil of the Berks silt loam is a brown or yellowish-brown silt loam, about 7 to 10 inches deep. The subsoil is a yellow friable silty clay loam, grading at 15 to 18 inches into a yellow friable silty clay. Usually this clay continues to a depth of 4 to 10 feet, where the bedrock of slate from which the soil is formed is encountered. Small, soft chips of the partially weathered slate, which is of the . . . Martinsburg formation, are fairly abundant throughout the soil section. These generally have an ocherous-yellow to reddish color. The soil of the Berks silt loam is similar to that of the shale loam, except that it has weathered deeper and contains a much smaller amount of the shale fragments throughout the soil mass.

Little difficulty is experienced in the cultivation of this soil, although, owing to the smaller amount of small shale fragments present, it has a more compact structure than the Berks shale loam.

The greater part of this type is in cultivation, and it is considered somewhat more productive than the shale loam. The same crops are grown and the same system of farming employed as on the Berks silt loam. Corn produces from 35 to 70 bushels per acre, oats 40 to 60 bushels, wheat 15 to 30 bushels, hay 1 ton to 2 tons, potatoes 125 to 250 bushels (or more), and rye 15 to 25 bushels per acre.

Hagerstown Loam

The Hagerstown loam (which represents mainly the residual weathering product of the limestones) is the most important and best developed as well as one of the most extensive soil types in the county. A large area in the southern part of the Great Valley comprises the greater part of the type. Entering the county to the west of Alburtis the Hagerstown loam, in a strip about 4 miles wide in this section, extends northeastward, widening to the north until at Allentown, in the eastern part of the county, the width is 8 or 10 miles. Macungie, Emaus (Emmaus), and Mountainville are along the southern border and Fogelsville, Siegersville, and Cementon are along the northern border of this area. Another important area of 8 or 10 square miles is encountered in the Saucon Valley, in the southeastern part of the county.

The type comprises broad valley lands and has an undulating to moderately rolling topography. The elevations range from a little less than 200 to a little more than 500 feet above sea level. There are a few steep slopes along the Jordan and Little Lehigh Creeks in Whitehall and South Whitehall Townships. Drainage is adequate, and the soil is retentive of moisture.

A few outcrops of the limestone parent rock are encountered, usually along the steep slopes near streams. In many places old pits, many feet deep, where iron has been mined, are found.

The Hagerstown loam is a brown mellow silt loam or silty loam, underlain at an average depth of about 8 inches by a yellow or reddish-yellow moderately friable silty clay loam, which between 15 and 20 inches passes into a reddish-yellow to yellowish-red crumbly clay. Generally the color becomes redder with increase in depth, being a dull red or a decidedly yellowish red below about 24 to 30 inches in the better-drained situations. In some of the flat and depressed situations, where drainage is not well established, the subsoil is often yellow or only slightly reddish yellow to a depth of 3 feet or more.

While most of the type is uniform there are a few variations. On slopes or on the tops of ridges where the surface has been eroded the silty loam surface soil is very shallow or has been entirely washed away, giving small areas of clay loam. In the cultivated fields these eroded spots are prominent by reason of their reddish color. These areas of clay loam are of but a few square feet to a few acres in extent, being too small to indicate on the map. Fragments of quartzite and sandstone are frequently present. In places these fragments are rather numerous. Small particles of quartz, quartzite, and sandstone, and a few stones, mainly quartzite and sandstone, upward of several inches thick, are disseminated throughout the soil section. Rounded quartzite boulders a foot or more in diameter are sometimes found on the surface. These are probably remnants of formations that have been largely removed by processes of erosion or represent fragments which have been brought in some way from the quartzite ridges. Where the Hagerstown loam adjoins the Berks shale loam some small fragments of the shale are present on the surface and in the soil.

When moisture conditions are favorable the Hagerstown loam is easily cultivated, working up with the ordinary tillage implements into a mellow and well-pulverized seed bed. If the soil is worked when wet, clods form on drying, but these are easily broken up by cultivation.

The Hagerstown loam is utilized almost entirely for general farming. It is considered the strongest and most productive upland soil in the county, and the general farm improvements indicate that it is the most valuable type. The original forest growth, consisting largely of white oak, has been cleared away, and practically all of the land is cultivated. The principal crops grown are corn, oats, wheat, some hay, and in certain sections potatoes. Dairying is also practiced to some extent. Corn produces 40 to 90 bushels per acre, averaging 50 to 60 bushels, oats 30 to 60 bushels, with an average of about 50 bushels, and wheat 20 to 35 bushels, probably averaging about 25 bushels per acre. From 1½ to 2 tons of hay per acre are produced. Rye is grown to a slight extent, yields ranging from 15 to 25 bushels per acre. Potatoes are grown for market in some sections, and produce with fertilization 150 to 250 bushels, and possibly more, per acre. A small amount of alfalfa is grown,[1] producing one-half ton to a ton per cutting, with three cuttings a season.

Hagerstown loam, gravelly phase.—The soil of the gravelly phase (due mainly to the admixture of glacial debris) is in most respects similar to that of the typical Hagerstown loam. The important difference is in the presence of water-rounded cobbles and gravel consisting of sandstone, quartzite, gneiss, limestone, and other rocks, and in its having a billowy surface such as might be described as hummocky or lumpy, with sink-hole depressions between the hummocks. There is not enough of the gravel and cobbles, however, to warrant the classification of this soil as a gravelly loam. There are many small patches of the Hagerstown clay loam on the slopes of the small ridges in this phase.

One area of this phase, about 2 square miles in extent, occurs just south of Mickleys. A variation of the phase extends westward from this area, and is similar to the gravelly phase in all respects except that there are very few rounded gravel in this soil, but numerous small, angular fragments of quartz, quartzite, and sandstone. This hummocky phase reaches from near Seiple to Siegersville in a strip a mile or more in width. Another body of this billowy variation extends southward from Walberts to East Texas in a body 2 or 3 miles wide. Agriculturally the variations are similar to the typical soil.

Hagerstown silt loam.—The silt loam phase of the Hagerstown loam is roughly coextensive with the argillaceous limestones of the Jacksonburg formation from which it has been mainly derived.

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[1] At present considerable alfalfa is grown. The potato yield has also been greatly increased.

The Hagerstown silt loam occurs in 3 areas, aggregating several square miles, along the northern border of the large area of Hagerstown loam and adjoining the Berks shale loam on the north. The largest area is located just south of Cementon in the eastern part of the county. There is another area near Fogelsville, and another in the western part of the county just north of Breinigsville.

This soil occupies smooth-sloped ridges and hills. It has a somewhat higher elevation than the surrounding Hagerstown loam. Surface drainage is good, and the soil is not subject to destructive erosion.

The soil of the Hagerstown silt loam is a brown mellow silt loam to an average depth of about 8 inches. This is underlain by a yellow silty clay loam to silty clay which is somewhat crumbly and extends to a depth of 3 feet or more. In the lower part of the subsoil grayish and whitish partially decomposed fragments of the parent rock are present in some areas, but very few rock fragments of any kind are present in the surface soil or in the upper part of the subsoil. Frequently the subsoil has a smooth, greasy feel. The lower part of the subsoil carries a little more silt and proportionately less clay than the upper part. It ranges from yellowish-red to reddish-yellow in color. In a few small areas the parent rock, a shaly limestone, locally called "cement rock," is near the surface, and fragments of the bluish-black shale are scattered over the surface.

The Hagerstown silt loam is easily cultivated and is devoted to general farming. It is a strong, productive soil, and good yields of all crops grown on it are secured. It has much the same agricultural value and is utilized for the same purposes as the Hagerstown loam.

Chester Stony Loam

This type is developed in small bodies scattered over the ridges and hills of the South Mountains, in the southern part of the county. (It is derived from the pre-Cambrian crystalline rocks.) It is closely associated with the Chester loam. The largest areas are found along the crests and slopes of the high ridge of the South Mountains, bordering the southern part of the limestone valley. South of the first main ridge, where the topography is less broken, the Chester loam occupies the greater area, but surrounds a number of bodies of the Chester stony loam.

The topography of this type is hilly to broken, and in many places the slopes are very steep and stony, in some cases being too steep for cultivation. Drainage is good throughout all parts of the Chester stony loam. The soil is fairly retentive of moisture.

The Chester stony loam is a brown or yellowish-brown loam or heavy loam, underlain at a depth of 5 to 8 inches by a yellow gritty clay loam or crumbly clay. In some places the soil is sandy or decidedly gritty. The subsoil occasionally has a slight reddish tinge, and in places it is reddish yellow. Fragments of the gneiss and granite parent rock, together with fragments of quartzite from associated beds, are present on the surface and in the soil body in amounts sufficiently large to give the soil a decidedly stony character. On the steeper slopes the parent bedrock is near the surface. Ordinarily the land cannot be satisfactorily cultivated until many of the stones are removed. Masses of rocks several feet in diameter are often encountered in the forested areas, and occasionally in cultivated fields.

The greater part of the type is forested with oak, birch, hickory, and poplar. However, some of it has been cleared of timber and the larger stones, so that the land can be cultivated. The same crops are grown and the same methods used as on the Chester loam. The fine earth of the type is practically similar to that of the Chester loam, and the land is nearly as high in agricultural value as that type. Yields are somewhat lower, and more difficulty is experienced in cultivation. This land could probably be utilized to better advantage for fruit, especially apples, than for the production of farm crops.

In recent years numerous apple and peach orchards have been planted on this soil.

Chester Loam

The Chester loam is a rather extensive type. It is developed over large areas in the southern part of the county. Being confined to the South Mountains region, these bodies occur just south of the limestone belt, and occupy a large part of Upper Milford and Lower Milford Townships. Smaller areas of the type are found in the same general region, in Salisbury and Upper Saucon Townships. Just east of Allentown there is a narrow strip of the type about 2 miles in length. In the limestone valley of Upper Saucon Township two small areas are found, surrounded by Hagerstown loam. One of these consists largely of a sandy loam soil, but owing to its small size it was not mapped separately. One small area 2 miles southwest of Emaus and one about a mile west of South Bethlehem have the same sandy characteristics. Altogether the sandy loam comprises a total area of but a few acres, and is therefore not shown separately on the map.

The surface of the Chester loam is rolling to hilly. Some of the slopes are quite steep, but cultivable, and in other places the topography is undulating. The type occupies the ridges and hills of the South Mountains. The tops of these hills are rounded and undulating to rolling, while the slopes are regular, but in places rather steep. The steeper locations, and sometimes the crests, are occupied by the Chester stony loam, while the smoother areas are usually the Chester loam.

The surface soil of the Chester loam is a mellow loam or silty loam, brown to yellowish brown in color, and having an average depth of about 10 inches. The subsoil consists of a yellow to reddish-yellow crumbly clay, which is very gritty and often contains a noticeable amount of mica flakes. In many places these mica flakes give the subsoil a greasy feel, while often the lower subsoil or substratum is composed largely of mica with other partially decomposed material of the parent rock. Fragments of the parent rocks, consisting mainly of gneiss and other crystalline rocks as well as some quartzite are scattered over the surface, but usually there are not enough of these to interfere materially with cultivation. The soil is easily cultivated and does not bake hard on drying.

No areas of the type are entirely free of stony material. In occasional small spots the soil is so stony as to resemble a stony loam. Many of the fields mapped as Chester loam were originally typical Chester stony loam, the bulk of the rocks having been cleared off in order that the land might be cultivated.

The original forest growth of chestnut, oak, hickory, and birch has been removed, and nearly all of the type has been in cultivation for many years.

The Chester loam is naturally a strong, fertile soil, and where care is taken to maintain its productiveness good crop yields are secured. The soil is naturally most productive where the surface is smoothest, for in areas of more irregular topography the parent rock is near the surface, the land is more stony, and the soil body is composed more largely of the fine rock fragments which give rise to the very gritty soil and subsoil.

The crops grown consist principally of corn, oats, wheat, rye, timothy, and clover. Dairy farming is an important industry on the type. Corn produces from 25 to 60 or 70 bushels per acre, oats 30 to 60 bushels, wheat 15 to 25 bushels, rye 15 to 25 bushels, hay 1 to 1½ tons, and potatoes 75 to 150 bushels per acre.

In recent years the growing of apples and peaches on this soil has increased in importance and potato growing has decreased.

Huntington Silt Loam

The alluvial soils of the various streams are classified as the Huntington silt loam.

The type occurs as narrow creek bottoms, and is encountered in all sections of the county. Some of this soil occurs along every stream in the county, but many of the areas are too narrow to be shown on the map. The widest areas are little more than one-fourth mile across.

The surface soil of the Huntington silt loam consists of 8 to 12 inches of a brown or yellowish-brown silt loam or silty clay loam. The subsoil is not altogether typical of the Huntington silt loam as elsewhere mapped, in that the yellow is more frequently mottled with gray. While the subsoil in places is a light-brown silty clay loam, it is more frequently a silty clay loam to silty clay of a mottled gray and yellow color. In the shale region the subsoil is somewhat sandy in places, and in the gneiss and granite region it is sandy and gritty. The largest area of the type is developed along Jordan Creek in the limestone region. The surface soil in this area is a brown silt loam, and the subsoil is a light-brown silty clay loam to silty clay.

The surface of the type is flat and but a few feet above the creek beds. The land, except in some of the larger areas, has very poor drainage and is wet for a large part of the time. Practically all of the type is subject to overflow. It is generally used for pasture or mowing land, some of the native grass being cut for hay. In a few places the land is cultivated. The soil is well adapted to corn, and yields of this crop are good. Wheat, oats, timothy, and clover also make fair yields on the well-drained areas.

Along the talus slopes of the mountain ridges in the southern part of the county several soils have been differentiated. These are the Dekalb stony loam, the Dekalb loam, and the Murrill loam. They contain abundant fragments of the crystalline rocks forming the ridges. Some of these areas have been cleared and cultivated.

In the area of Triassic shales and conglomerates of the southeastern parts of Lower Milford and Upper Saucon townships several soil types have been noted, including the Penn gravelly loam, Penn shale loam, Penn stony loam, Penn silt loam, Montalto stony loam, Montalto clay loam, Lickdale clay loam, Lansdale silt loam, and Lansdale stony loam. These soils are mainly red. Where the cobbles are not too abundant the soils are fertile and readily cultivated.

The limestone area with a cover of glacial loam, sand, and gravel extending across Hanover Township as a band about a mile in width from Bethlehem to the Lehigh River and a short distance into Whitehall Township contains soil designated as the Wheeling gravelly loam and Wheeling loam. They are scarcely separable from the Hagerstown loam in characteristics and uses.

Besides these soils there are some stony areas, especially in the South Mountain ridges, where soil is lacking, various dumps about the old mine holes, and piles of slag near the old iron furnaces.

AGRICULTURE

The position of Lehigh County in agriculture deserves some attention in connection with the discussion of the soils of the county. Some of the census figures are therefore given. The county leads all other counties of the State in the production of Irish potatoes.

Census of Lehigh County farms

Item	1940	1930
Number of farms	2,074	2,325
Full owners	1,488	1,731
Part owners	192	74
Managers	31	74
All tenants	363	446
Value of farms (land and buildings)	$13,709,179	$21,806,201
All land in farms, acres	152,385	160,314
Average acreage per farm	73.5	69.0
Horses and colts	3,381	5,016
Cattle	9,823	10,611
Hogs and pigs	9,522	12,841
Corn for all purposes, acres	18,616	18,315
Corn for grain, acres	17,640	17,480
bushels	543,785	607,238
Wheat threshed, acres	20,128	25,542
bushels	400,112	464,416
Oats threshed, acres	11,031	10,133
bushels	262,398	271,853
Oats cut and fed unthreshed, acres	419	439
Barley threshed, acres	2,530	1,276
bushels	77,531	23,860
Rye threshed, acres	974	2,706
bushels	13,741	42,635
Mixed grains threshed, acres	190	189
bushels	4,673	5,069
Irish potatoes, acres	12,626	13,560
bushels	1,483,067	1,681,211
All hay, and sorgums for forage, acres	25,654	24,729
tons	26,006	33,650

MINERALOGY

By Benjamin L. Miller

Lehigh County has yielded a fairly large variety of minerals, somewhat less than some of the counties of the southeastern portion of the State, but far more than the northern, central and western counties. The variety is due largely to the different types of rock present in the county. These include acid, intermediate, and basic igneous rocks, both deep-seated (plutonic) and shallow (extrusive); sedimentary rocks of the principal types—conglomerate, sandstone, shale and limestone; and metamorphic rocks—gneiss, schist, quartzite, marble, and slate. The glacial deposits that are thinly spread over part of the county yield a great variety of rocks collected by the ice from a wide area to the northeast. These rocks are composed of many minerals.

In general each type of rock serves as the home of particular minerals, as must be the case since rocks are principally classified by their mineral composition. The metamorphosed igneous rocks contain the largest variety and the slightly altered sedimentary ones the fewest.

In Lehigh County the crystalline rocks occupy a comparatively small area in the southern section but they contain several somewhat unusual minerals. The pegmatite dikes that cut through the metamorphic gneisses have yielded several economic minerals, but in quantities too limited to be of commercial importance. The pegmatites have furnished some good mineral specimens. The gneisses themselves are composed of numerous minerals, mainly silicates, but the individual grains are small and the associated minerals are not readily separated. Some minerals have been recognized only under the microscope.

The sedimentary rocks, limestone, sandstone, and shale are composed of a limited number of minerals, mainly oxides and carbonates. The normal minerals are mainly small and the individual grains not readily recognizable with the naked eye. They are cut by veins that may carry other minerals.

The surface alteration and weathering of all the rocks have resulted in several secondary minerals which, in a few cases, possess economic significance, particularly the iron ores and clays.

Most of the geological work in this region has been done by men primarily concerned with the economic mineral products or the stratigraphy and there have been comparatively few strictly mineralogical investigations. While Professor of Chemistry in Muhlenberg College, Dr. Edgar Fahs Smith searched for minerals through Lehigh County and analyzed many of the specimens found. These results he published in 1882, 1883, and 1885. Similar contributions were made by John Eyerman in 1889 and 1911. Owing to the fact that the articles by Dr. Smith and Mr. Eyerman are not readily accessible, nearly all of their descriptions of Lehigh County minerals are quoted in full. Frederick A. Genth collected all the known mineralogical data of the State in his "Preliminary Report on the Mineralogy of Pennsylvania" published in 1875. Samuel G. Gordon in his "Mineralogy of Pennsylvania," published by The Academy of Natural Sciences of Philadelphia in 1922, brought the information up to date. The latter is a valuable contribution and has been freely used in the preparation of this chapter.

Frederick Prime Jr. reported and described numerous minerals in his investigations of the iron ores of the region. Numerous other geologists have added to our knowledge of the minerals of Lehigh County in minor ways. Many of the articles deal with the minerals found in or near the Friedensville zinc mines of the Saucon Valley.

The list of minerals that follows is believed to be almost complete, according to existing information. Undoubtedly, additions will be made from time to time, especially in the microscopic investigations, and new occurrences will be reported. This chapter is largely a compilation of previously published material, scattered through many volumes, and supplemented by the author's personal observations.

List of Minerals

- *Native elements*
  - Copper
  - Graphite
  - Sulphur
- *Sulphides*
  - Chalcocite
  - Galena
  - Greenockite
  - Iron minerals
    - Marcasite
    - Pyrite
  - Molybdenite
  - Sphalerite
- *Halides*
  - Fluorite
- *Oxides*
  - Corundum
  - Iron minerals
    - Anhydrous
      - Hematite
      - Martite
      - Magnetite
      - Ilmenite
    - Hydrous
      - Goethite
      - Limonite
      - Turgite
  - Manganese minerals
    - Psilomelane
    - Pyrolusite
    - Wad
  - Silica minerals
    - Quartz
    - Chalcedony
    - Flint (basanite)
    - Jasper
    - Hyalite
  - Spinel
- *Carbonates*
  - Calcium minerals
    - Calcite
    - Aragonite
    - Dolomite
  - Copper minerals
    - Azurite
    - Malachite
  - Lanthanite
  - Siderite
  - Zinc minerals
    - Hydrozincite
    - Smithsonite
- *Silicates*
  - Feldspar group
    - Orthoclase
    - Plagioclase
  - Garnet group
    - Almandite
    - Andradite
  - Mica group
    - Biotite
    - Muscovite
      - Damourite
      - Sericite
      - Pinite
  - Amphibole group
    - Hornblende
    - Crocidolite
    - (Glaucophane)
    - Actinolite
    - Asbestos
  - Pyroxene group
    - Augite
    - Diopside
    - Enstatite
    - Hypersthene
    - Pectolite
- *Other anhydrous silicates*
  - Allanite
  - Calamine
  - Epidote
  - Sillimanite
  - Titanite
  - Tourmaline
  - Zircon
- *Hydrous silicates*
  - Allophane
  - Chloropal
  - Halloysite
  - Kaolin
  - Serpentine
  - Stilbite
- *Phosphates*
  - Wavellite
- *Uranates*
  - Uraninite
- *Sulphates*
  - Goslarite
  - Melanterite

Descriptions of Individual Minerals

In the descriptions of the individual minerals which follow, little is given other than the particular features that characterize the Lehigh County specimens. It has not seemed desirable to describe the ordinary properties which are contained in all textbooks on mineralogy. The crystallographic descriptions are largely omitted since their inclusion would necessitate the reproduction of crystallographic drawings in most instances. Most of the available chemical analyses are included, even though some of them are of doubtful accuracy. It seems unnecessary also to discuss the various problems of nomenclature and chemical formulæ.

The minerals that have been mined and utilized are discussed more fully in that portion of the volume dealing with the economic geology.

Instead of the full bibliographic reference for each citation or quotation, only the author's name and the year of publication are given. The full title can be found readily by reference to the chapter on Cartography and Bibliography. For one who wishes to obtain all the information available, it will generally be necessary to refer to the individual articles.

NATIVE ELEMENTS

Copper (Cu)

Native copper has been twice reported from the Ironton Mines as follows:

"An interesting occurrence (of native copper) has been noticed by Prof. W. Th. Roepper in the limonite deposits of Ironton, Lehigh County, where it is occasionally met with in minute distorted, probably cubical crystals disseminated through quartz." (Genth, 1875, p. 5.)

"Of more interest to the mineralogist is the occurrence of native copper in this black clay (of the Ironton Mines), which is found in small filiform pieces. Its presence in the metallic state being probably due to the carbonaceous matter in the clay." (Prime, 1878, p. 41.)

Graphite (C)

Graphite in thin flakes has been noted at several places in the metamorphosed rocks of Lehigh County. In two different places attempts have been made to open mines for the purpose of obtaining it in commercial quantity. These are described in the chapter on Mineral Resources.

The most numerous occurrences of graphite in the region are in the acid and basic gneisses of South Mountain. About half a mile west of Seidersville, along the Lehigh-Northampton County line, small, thin flakes have been noted in the basic gneiss. Flakes of graphite have been noted in the gneiss along the Little Lehigh west of the Western Salisbury Church. On the crest of South Mountain about three-fourths of a mile east of Emmaus and the same distance east of Vera Cruz, graphite flakes are so numerous that exploratory shafts were dug.

The microscopic examination of some of the gneisses has revealed the presence of tiny flakes indistinguishable to the naked eye.

In the cement rock of the Jacksonburg formation, the carbonaceous matter of these argillaceous limestones has been converted into what is assumed to be graphite along slickensided surfaces. These smooth, brightly polished surfaces are mainly along bedding planes and are abundant in the rock of many quarries. The graphite rubs off readily. Veins of calcite and quartz have developed along these slippage planes and it is common to find fine specimens of veins coated on both walls with a film of graphite.

Graphite is present as a microscopic constituent in most of the commercial slates of the county. Behre (1933, p. 180) describes it occurring in slate as rounded, discoidal, or lenticular specks up to 0.015 mm. in diameter.

Sulphur (S)

The only known published description pertaining to native sulphur in Lehigh County is the following:

"Some good sized masses of sulphur were found by me, several years ago at the Ueberroth mine, Friedensville, Lehigh County, probably resulting from the desulphuration of the sphalerite." (Eyerman, 1889.)

In some of the iron mine dumps composed of clay and considerable pyrite it is not uncommon to note a thin encrustation of fine yellow sulphur crystals. Some sulphur crystals are present in the weathered pyrite of the pyrite prospect shaft on the slope of South Mountain southwest of Wilbur.

SULPHIDES

Chalcocite (Cu_2S)

No actual occurrence of chalcocite is known in Lehigh County, although it may well be found in association with malachite in Flint Hill in the extreme southeastern corner of the county.

"According to a private communication from Prof. W. Th. Roepper, of Bethlehem, chalcocite, occasionally in small crystals, is frequently met with on the line of junction between the South Mountain rocks and the Triassic sandstone, which latter is often colored green by malachite, resulting from the oxidation of the chalcocite." (Genth, 1875, p. 16.)

Galena (PbS)

The writer has not seen nor heard of any specimens of galena being found in Lehigh County, but is convinced that it is occasionally present in small isolated grains in the quartz veins that cut the Shawangunk sandstones and conglomerates of Blue (Kittatinny) Mountain. He has noted it in the railroad cut on the east side of Lehigh Gap and in the same strata farther east. He has seen it in larger amounts in the same formation near Bellefonte, where, in 1915, an unsuccessful attempt was made to mine it. Similar occurrences are reported from the Shawangunk Mountains of southeastern New York.

Greenockite (CdS)

The only known occurrence of greenockite in Lehigh County is in the Friedensville zinc mines where it was found by Prof. Roepper. It occurs mainly as yellow, greenish-yellow, or orange-colored earthy (amorphous) encrustations on sphalerite, calamine, or the dolomitic limestones. Roepper also noted it in the residual clay resulting from the decomposition of pyritiferous limestone. He analyzed a specimen of this material and found it to contain 5 percent of cadmium. Genth (1875, p. 19) says "formerly cadmium was separated from the zinc at the Bethlehem works." This statement is questioned.

Marcasite (FeS_2)

Few exact determinations of marcasite have been made in the region, although it is the general belief that it is fairly common in association with pyrite. Some of the massive iron sulphide has the characterictic appearance of marcasite and, furthermore, the readiness with which much of it decomposes when exposed to the atmosphere likewise indicate its presence. This is particularly true of iron pyrite in the Friedensville zinc mines and to a lesser degree in some of the limonite mines.

Pyrite (FeS_2)

Pyrite is a common mineral in Lehigh County. In places it is a rather abundant constituent of the gneisses, being well distributed through the normal gneiss and in the pegmatites cutting the gneiss. It occurs almost everywhere in the Hardyston sandstone and by oxidation makes the limonitic stains that render the stone particularly pleasing in color for residences and public buildings. In the compact quartzite the oxidation has extended inward from the bedding and joint planes less than an inch, but in the more porous beds the pyrite has changed to limonite throughout, even though the layers be six inches or more in thickness.

Pyrite is common in all the limestones, especially in those high in argillaceous and carbonaceous matter. Usually it is in small cubes along bedding planes, but is also present in massive form.

Considerable pyrite was encountered in the lower levels, in several of the limonite mines once worked in the county, both in those deposits contained within the Hardyston quartzite and within the limestones. As suggested in the discussion of the origin of iron ores, this furnishes some evidence for the view that all the iron of the limonite ores was derived from pyrite. The commercial aspects are discussed in the chapter on Mineral Resources.

Pyrite is fairly common in the Jacksonburg cement rock, particularly associated with the graphite occurring along slickensided surfaces.

In the Martinsburg slates one occasionally notes small cubes of pyrite or cavities resulting from their removal. In some of the black "ribbons" of the "hard vein" slate the presence of considerable pyrite (and marcasite?) results in fairly rapid decomposition and disintegration.

Molybdenite (MoS_2)

Molybdenite in thin coatings along joint planes in gneiss has been observed in several places by the writer, but the only occurrence known in Lehigh County where the associated rock is in place is in an abandoned quarry in a dense granite gneiss a short distance south of the Reading Railroad about three-fourths of a mile east of Vera Cruz. When the rocks are broken it is not uncommon to find bright fresh pieces of the mineral. Flakes of molybdenite associated with secondary quartz and epidote were noted in loose masses of basic gneiss on the lower slope of South Mountain south of Farmington. It also occurs in some of the gneisses associated with the hematite iron ore mine just west of Old Zionville.

Sphalerite (ZnS)

The outstanding occurrence of sphalerite in Pennsylvania is at Friedensville, where zinc ores were mined over a period of years. This deposit is described in detail in the chapter on Mineral Resources.

Small particles of sphalerite have been reported also from some of the limonite mines in Saucon Valley, particularly from the Greene Mine, slightly less than one mile east of Lanark. On May 20, 1933 the writer found a greenish-yellow sphalerite associated with crystalline dolomite within a grayish-white chalcedony lens in an old limestone quarry a short distance southwest of the junction of the Little Lehigh and Jordan creeks, South Allentown. The limestone belongs to the Allentown formation. Other similar discoveries will doubtless be made.

HALIDES

Fluorite (CaF_2)

Fluorite has been noted by the writer and others in numerous places throughout the State, especially in calcite or dolomite veins in the limestones. Most of it is purple, but the light green variety has also been found.

In recent years both purple and green fluorite have been found in calcite veins in the Ormrod quarries of the Lehigh Portland Cement Co. It is probably this same locality that furnished the specimens analyzed and described by E. F. Smith in the following quotation:

> About one and a half miles southeast of the above locality (Ironton iron mines) are the limestone quarries of Mr. Kleckner. In them have been discovered veins of beautiful fluorite and fine quartz crystals. The former mineral occurs intimately mixed with the limestone, and presents itself in the most beautiful green, purple and pink colors. Upon several specimens octahedral forms were observed, but not very distinct. It is seldom that entire crystals can be procured, since blasting is invariably necessary to reach them; consequently fragments are the result. Quantitative analyses of the purple and green varieties were made.
>
> | Purple variety: | | | |
> |---|---|---|---|
> | | Fl | 49.20 | per cent. |
> | | Ca | 50.87 | |
> | | Fe_2O_3 | trace | |
> | | | 100.07 | |
>
> The mean of the specific gravities of five specimens was 3.21; ranging from 3.17-3.24. The shade of purple varied very much in the specimens examined.
>
> | Green variety: | | | |
> |---|---|---|---|
> | | Fl | 49.00 | per cent. |
> | | Ca | 50.91 | |
> | | Fe_2O_3 | trace | |
> | | | 99.91 | |
>
> Sp. gr. about the same as in case of the purple. South of Emmaus in the Lehigh mountains Mr. Benj. Sadtler, Jr., found this mineral in perfect octahedra of deep purple color in a granitic rock. (Smith, 1883, p. 272.)

The rather widespread but sporadic occurrence of small particles of fluorite in both the pre-Cambrian and Paleozoic strata of the State brings up the question of its origin. Although at the present time there seems to be a preference among geologists for the belief in magmatic waters as the source, the writer strongly inclines to the belief that most, if not all, the occurrences of fluorite in limestone known to him within the State have been formed by artesian waters of meteoric origin.

Fluorite is also present in the baked Triassic conglomerates south of Hosensack in Lower Milford Township.

OXIDES

Corundum (Al_2O_3)

Edgar F. Smith and N. W. Thomas first reported the discovery of corundum about three-fourths of a mile north of Shimersville in 1882. Following their announcements an attempt was made to mine the material. A trench was dug in the decomposed gneiss and the corundum crystals were picked out by hand. A small shipment is reported to have been made. The writer has picked up small pieces in the vicinity of the trench, now almost obliterated. The indications are that the corundum occurs in a pegmatite dike cutting the gneiss. The descriptions by Smith and Thomas are quoted:

> Early in January last, a piece of what was once a large hexagonal prism of corundum terminated by pyramids, was handed us. The specimen we received was an end piece exhibiting a perfect hexagonal form, with pyramidal ending, and on the broken surface of the crystal, the color observed was blue. The weight of this specimen is five pounds. The original complete crystal measured eight inches in length, and the diameter over the secondary axes is about four and one-half inches. On the exterior surface are observable here and there, magnetite crystals and these were the cause of the destruction of the original crystal soon after it had been plowed up. The farmer thinking he had made a valuable discovery and curious to know the appearance of the inside, broke the crystal into several pieces, one of these coming into our possession, after it had been carried about to various parties, for inspection and determination. Only very slight indications of any alteration are apparent on the exterior of the crystal. Soon after getting the above, we received another crystal—a double pyramid—about five and one-half inches long and weighing over five pounds. Since the reception of the preceding, we obtained several cigar boxes full of smaller, well-defined crystals. All of our specimens were found near Shimersville, Lehigh County, Pa., and were thrown out while plowing. The district over which these crystals were scattered, and have been noticed, is rather extensive and is already under lease, and "prospecting" for larger quantities has been commenced. Quite a number of medium sized crystals were sent to the Weissport Emery Works, there tested and declared excellent for technical purposes. We reserve our analyses of the above for a future communication. (Smith and Thomas, 1882.)

> This mineral, which we announced (Am. Phil. Soc., March 17, 1882) as occurring near Shimersville, Upper Milford Twp., has since been discovered there in exceedingly fine crystals; color grayish and red. In many the star is very distinct. The specimens are but slightly altered. The brilliant black crystals noticed upon almost all specimens from here have been found to be menaccanite. Dr. Genth (Am. Phil. Soc. Proceedings, Aug. 18, 1882) has published an account of the black spinel found here, which is unquestionably an alteration of the corundum. Very recently several students of this laboratory discovered fine specimens of it. An analysis of the Shimersville corundum gave the following:

SiO_2	3.28	per cent.
H_2O	1.37	
Al_2O_3	85.75	
Fe_2O_3	4.26	
TiO_2	2.74	
MgO	trace	
CaO	1.99	
	99.39	

Sp. gravity, 3.898 (Smith, 1883.)

Hematite (Fe_2O_3)

Hematite as a red ocherous coloring matter is fairly common throughout the rocks of the county. It has been formed from pyrite and is commonly associated with limonite. Earthy forms of hematite occur about the old iron mines. Doubtless some of the so-called hematite is actually turgite.

The brown hydrous iron ore minerals so extensively worked throughout the county were commonly called "hematite" or "brown hematite." They are actually limonite or mixtures of several hydrous iron minerals.

Hosensack Station and Shimersville have been cited as localities where hematite has been found.

Martite (Fe_2O_3)

Martite as a pseudomorph after magnetite or pyrite has been recognized in various places but rarely except where it preserves the crystal form of the replaced mineral. The writer has noted it occasionally and "Prof. W. Th. Roepper has observed that it is frequently associated with zircon, allanite, etc., at several of the South Mountain localities near Bethlehem." (Genth, 1875, p. 35.)

Magnetite (Fe_3O_4)

Magnetite is a common accessory mineral in the gneisses of the region, especially the more basic varieties. As the containing rocks decompose, the small magnetite particles are freed and are concentratd by the hillside run-off following rains. The black grains can be readily seen along gullies and in the stream sands.

Magnetite has been found in commercial quantity in several places, as described in the chapter on the Mineral Resources.

Ilmenite (Menaccanite) ($FeTiO_3$)

Ilmenite is a common constituent of the metamorphic crystalline gneisses of the region, occurring in small grains associated with magnetite. The black sand resulting from the concentration of the heavy minerals from the decomposed gneisses practically always contains ilmenite.

In some of the older literature this mineral is called menaccanite, a term at present obsolete.

Prime describes a specimen found at the Elias Daney mine a short distance northeast of Leiberts Gap as follows:

> The foreman at the mine had a single specimen of ilmenite (titaniferous iron ore) which he said had been found in the top clay when working the mine. This was sent to Mr. A. S. McCreath, who analyzed it and reported:

Silica	8.37
Lime	0.52
Magnesia	3.87
Alumina	2.79
Titanic acid	32.18
Phosphorus	trace
Sulphur	none
Manganese	0.35
Iron	38.16

> This latter partly as ferrous, partly as ferric oxide. This specimen is evidently extraneous, as but a single one has been found. (Prime, 1878, p. 26.)

Goethite ($Fe_2O_3.H_2O$)

Goethite has usually not been distinguished from other hydrated iron oxides, but it appears to be present in most of the brown iron ore deposits of the region, particularly in the iron geodes that were abundant in some of the limonite mines.

Limonite ($2Fe_2O_3.3H_2O$)

Hydrated iron oxides are abundant throughout the county. The term limonite is used to designate those mixtures of ferric iron minerals whose constituents have not been identified. The principal constituents are goethite, lepidocrocite, turgite, hematite, and jarosite. (Galbraith, 1937.) The brown limonite was the principal constituent in the numerous brown iron ore mines once worked but now abandoned. The miners called it brown hematite. Undoubtedly much of what has been loosely called limonite is actually goethite or lepidocrocite. It occurs in many forms. The earthy variety mixed with clay is known as ocher and has been used for paint. The shelly, stalactitic and geode varieties are common. The black varnish-like botryoidal lining of geodes and other cavities reveals a fibrous structure upon fracturing. Although this has been called limonite in the past, it probably is goethite.

Limonite is the chief coloring matter of most of the rocks of the region. The iron was originally derived from pyrite, siderite, and the various ferro-magnesian minerals of the crystalline rocks. Pseudomorphs of limonite after pyrite have been found.

A full description of the limonite ores is given in the chapter on Mineral Resources.

Turgite ($2Fe_2O_3.H_2O$)

Turgite has been confused with others of the iron oxides. Posnjak and Merwin * make the statement that "the fibrous mineral *turgite* is variable in composition and considerable evidence is given that it probably represents solid solutions of goethite with hematite together with enclosed and absorbed water."

Reddish iron oxides are not uncommon in the numerous limonite deposits in Lehigh County. Many of these specimens have been called turgite.

Psilomelane (MnO_2 + impurities)

Most of the limonite ores of the region contain some manganese and in a few places considerable percentages of it. The ocher in some localities contains considerable manganese. Although some of the manganese in the iron ores may be in the form of pyrolusite, it seems that more exists as psilomelane and of the variety known as wad.

Further descriptions are given in the discussion of manganese ore in the chapter on Mineral Resources.

Pyrolusite (MnO_2)

Dendrites of pyrolusite, resembling ferns and frequently so designated, are common in the rocks of the region. Extending in from the cracks in the rocks the dendrites are very conspicuous, especially in some of the limestones.

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* Posnjak, E., and Merwin, H. E., The hydrated ferric oxides: Am. J. Sci., 4th ser., vol. 47, p. 347, 1919.

Nearly all the limonite ores, once so extensively mined in this region, carried some manganese either as pyrolusite or psilomelane. Some of the "mountain ores" were especially high in manganese. A few specimens of stalactitic pyrolusite were found at one of the iron mines southeast of Wilbur.

Dr. Edgar F. Smith contributed the following description:

"At various times miners have reported this mineral as occurring in Lehigh county, but only of late have finely crystallised specimens of it been observed. The crystals are usually seen upon the inside of limonite nodules, frequently covering their entire inner surface. Those in our possession are from the Lehigh mountain south of Allentown, near the village of Mountainville:

SiO_2	9.93	per cent.
Fe_2O_3	4.21	
Al_2O_3	trace	
MnO_2	82.66	
Mn_3O_4	3.13	
	99.93"	

(Smith, 1883, p. 277.)

Wad (MnO_2 + impurities)

The soft earthy variety of manganese oxide mixed with various impurities and known as wad has the same occurrence and association as psilomelane and pyrolusite.

Genth (1875, pp. 53-54) offers the following:

"It has been observed as a frequent associate of limonite ores. Most of the wad or bog manganese of the limonite region of Northampton, Lehigh, Berks, Montgomery and other counties, contains some cobalt.

"A large deposit of an ocherous cobaltiferous variety occurs, according to Prof. Roepper (priv. com.) near Albertis (Alburtis), Lehigh County, at the mine of the Philadelphia and Reading Coal and Iron Company."

....

"Some varieties of the Lehigh region contain a considerable admixture of clay, as is shown by the analysis of one by Prof. W. Th. Roepper (priv. com.).

"He found:

Clay	45.66	per	cent.
Ferric oxide	19.29	"	"
Manganic oxide	23.64	"	"
Magnesia	0.34	"	"
Phosphoric acid	0.29	"	"
Water	11.04	"	"
	100.26	"	"

SILICA MINERALS

Quartz (SiO_2)

Quartz is the most widely distributed mineral in the world and occurs in many different varieties and under various conditions. It is an essential or an accessory mineral in practically every type of rock within the county.

The light-colored or acid gneisses contain grains of quartz associated with the feldspars and ferro-magnesian minerals; the dark-colored gneisses in places carry a small amount of quartz; all kinds of gneisses are cut by thin quartz veins and by pegmatites in which the quartz grains may be of considerable size; the Hardyston conglomerates, sandstones and quartzites are composed almost entirely of quartz, both the clastic particles and the cementing matter; all the limestones carry quartz grains and are cut by thin veins in which calcite and dolomite are most abundant but in which quartz is common; the Martinsburg shales contain small quartz grains and in many places have many veins of quartz or quartz and calcite; and the Triassic conglomerates consist of quartz pebbles in a matrix of shale that contains many quartz grains.

Quartz crystals up to four inches in length with well developed crystal faces have been found in cavities in the fractured limestones and loose in the residual soils.

In that part of the Saucon Valley contained in Lehigh County some masses of ferruginous quartzite, probably from the Beekmantown formation, have been found in which each grain has some crystal faces and some individual particles are perfect doubly-terminated crystals. They can readily be seen through a small hand lens.

Genth reports "an interesting variety of fibrous quartz (which had been considered petrified horsehair), with zinc blende and limonite, at the zinc mines at Friedensville, near Bethlehem." (Genth 1875, p. 57) He also states that fetid quartz has been found in the same mines. (p. 59)

Chalcedony (SiO_2)

Associated with the abundant yellow jasper in the Hardyston formation which normally crops out along the lower slopes of South Mountain, there are occasional milk-white to light-blue, partially translucent masses of chalcedony. In a quarry in Allentown limestone near the junction of the Little Lehigh and Jordan creeks there is a thin layer of chalcedony that has been formed by replacement of the limestone.

Flint (basanite, hornstone, chert) (SiO_2)

The dark-colored cryptocrystalline varieties of silica, although described as possessing somewhat different properties, are not here differentiated. Specimens of each type and gradations from one to another can be picked up in the fields or along the streams throughout the areas underlain by limestone. The source of the flint is in the Cambrian and Ordovician dolomitic limestones. In some places it is fairly abundant. All these limestones have a rather high silica content and the silica has, in part, been segregated by underground circulating waters into lenses or nodules of irregular shape. The lenses are commonly more or less parallel to the bedding planes and range in thickness up to several inches. Many specimens show by their physical features that they are replacements of the limestone. Replacements of the fossil algae *Cryptozoon proliferum* by flint have been found. Occasional irregular masses of flint several feet in diameter cut across the beds. The Beekmantown limestone of the Friedensville zinc mines contains an abundance of flint.

The flint in the soils is the residual, relatively insoluble material left behind when the enclosing dolomitic limestone was removed by solution.

The Indians used the black flint of the region for their arrowheads, many of which have been collected all through the county.

Jasper (SiO_2)

Yellow and red jasper are abundant in the Hardyston formation of the southeastern part of the county. The yellow variety is most common. Some of it is uniform in color, but most of it is mixed with clear quartz and much is stained with pyrolusite. The yellow variety grades from a bright golden yellow to a dark brown, and the red from an orange to a brick color or to a deep carnelian red.

The Indians found the jasper very satisfactory for their arrow heads, spear heads and scraping knives. These have been found all over the county and far beyond its borders. Loose pieces of jasper suitable for implements were probably picked up in many places on the lower slopes of South Mountain. In two places excavations of considerable depth were made. Two of the most important sites in the State for digging the material are within the county, one of them on the hill about a quarter of a mile northwest of Vera Cruz and the other about half a mile southeast of Macungie. Another important one is located in Berks County a short distance beyond the borders of Lehigh County. These diggings are described in the chapter devoted to the early history of the county.

The jasper is considered to be a replacement of the Hardyston sandstone inasmuch as petrographic study has revealed some rounded sand grains* although in general no original structures are preserved. Much of the jasper is shattered and cavernous, with the walls of the cavities lined with beautiful small quartz crystals. Some specimens of this drusy variety of jasper have been used in rock gardens and walls because of its beauty.

Jasper has also been noted in a few of the limonite mines in the limestone areas. In such occurrences it has doubtless been formed by replacement of limestone.

Hyalite (SiO_2nH_2O)

F. R. Faux reports the presence of hyalite in the baked Triassic sediments south of Hosensack, Lower Milford Township.

Spinel ($MgAl_2O_4$)

Genth reports spinel from the corundum locality near Shimersville in the following description.

"Disseminated through all the crystals (of corundum) and frequently accumulating on the surface, are minute, very brilliant crystals of a highly titaniferous menaccanite; these are *not* magnetic. It appears that this corundum has not been altered to a very great extent, only a few specimens of black spinel in irregular masses or rounded, pyramidal forms have been found, besides these only very thin yellowish or greenish, soft coatings, in very minute quantity, which may be a potassium mica. I could not get enough for examination. The spinel has an iron-black color, and is slightly magnetic. Its specific gravity is $= 4.056$.

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* Fraser, Donald M., Replacement of Hardyston quartzite by jasper: Pennsylvania Acad. Sci. Proc., vol. II, pp. 57-61, 3 figs., Harrisburg, 1937.

"Mr. George M. Lawrence has made an analysis of it in the Laboratory of the University of Pennsylvania, and found, after deducting 1.47% of silicic acid as follows (a); the calculated composition (b).

a		
Al_2O_3	=	56.42
Fe_2O_3	=	13.17
FeO	=	22.95
MgO	=	4.94
TiO_2	=	2.62
		100.10

b		
$MgAl_2O_4$	=	25.40
$FeAl_2O_4$	=	48.51
$FeFe_2O_4$	=	26.09
		100.00

"The titanic acid is present evidently as a mechanical admixture of menaccanite $FeTiO_3$; deducting this and 24.16% of corundum, the composition of the pure spinel is given under (b). I do not consider the $FeFe_2O_4$ a mechanical admixture of magnetite, as it cannot be dissolved out by hydrochloric acid." (Genth, 1882.)

CARBONATES

Calcite ($CaCO_3$)

Calcite is an abundant mineral throughout Lehigh County. Its most abundant occurrence is in the Cambro-Ordovician limestones where it is the principal constituent mineral. It is present also as a vein mineral, commonly in association with quartz, in the limestones and shales. Some beds of limestone are composed of practically pure calcium carbonate, but most contain varying amounts of other minerals, particularly dolomite.

Calcite (and quartz) vein matter is strikingly shown in the Jacksonburg cement rock in many quarries. The contrast of the black cement rock and the white mineral veins produces an attractive effect. These calcite veins are normally finely crystalline but here and there cleavage rhombs up to an inch or more in diameter can be found.

Occasional small cavities in the limestones contain calcite crystals, varying from the acute scalenohedral form (dogtooth spar) to the flattened form (nail-head spar). Some of the crystals are transparent although most are tinted a light yellow and are only translucent. The mineral collector rarely finds any specimens of museum value.

Although there are no large caves in the county there are solution cavities in many places in the limestones where calcite stalactites have been found. A small cave in the Ziegenfuss quarry in the southwest part of Allentown at one time yielded some beautiful specimens of calcite and aragonite.

Genth reports stalactitic calcite in the form of "hollow quills at Catasauqua." (Genth, 1875, p. 154.) The exact locality is unknown to the writer.

Aragonite ($CaCO_3$)

Clusters of tiny, acicular and tree-like crystals of aragonite are occasionally noted in the cavities in the limestones. F. R. Faux reports beautiful arborescent forms found in a cave in the Ziegenfuss quarry in the southwest part of Allentown. These are very fragile but make very attractive specimens. Many stalactities in open caverns are composed of aragonite.

Genth describes aragonite from Friedensville as follows:

> "A highly interesting zinciferous variety of aragonite, in crystals of three-fourths to one inch in length, forming radiating groups of a white and yellowish-white color, has been observed at the Friedensville Zinc Mines, by Prof. W. Theo. Roepper, who kindly furnished me with his analysis.
>
> "It contains
>
> | | |
> |---|---|
> | Carbonate of lime | 94.20 |
> | Carbonate of zinc | 4.73 |
> | Insoluble | 0.53 |
> | | 99.46 |
>
> "Most of the aragonite from Friedensville contains carbonate of zinc." (Genth, 1875, pp. 162-163.)

Dolomite ($CaMgCO_3$)

Dolomitic limestones are widespread throughout the limestone belts of the county. In small cavities in these limestones it is not unusual to find small saddle-shaped crystals of dolomite. Some fine specimens are to be found in the rock waste beside the open pit of the Ueberroth zinc mine, Friedensville.

The magnesium carbonate in the magnesian limestones ranges up to approximately 45 percent. With the exception of the Jacksonburg limestones used in manufacture of portland cement and occasional beds within the Beekmantown formation, it is unusual for any limestone from Lehigh County to show less than 5 percent $MgCO_3$, thus indicating the widespread occurrence of dolomite.

Azurite ($Cu_3(OH)_2(CO_3)_2$) and Malachite ($Cu_2(OH)_2CO_3$)

Azurite and malachite are included in the minerals of Lehigh County although no actual occurrence is known to the writer. On the north slope of Flint Hill, a part of which comprises the extreme southeastern corner of the county, some prospecting for copper ore was carried on about 30 years ago. Malachite coatings of limestone pebbles in the Triassic limestone conglomerate were fairly abundant. Some of the limestone pebbles had been removed by solution, leaving cavities whose sides were covered by a thin film of malachite. Inasmuch as the same rock formation extends into Lehigh County it is probable that careful search may show that malachite occurs in this county as well. Azurite commonly is associated with malachite so that it may also be present.

Lanthanite ($(La_2,Ce_2)(CO_3)_3.8H_2O$)

Probably the rarest mineral thus far reported in the county is lanthanite. Only a single specimen has come to light even though extended search has been made for more material.

In 1853 Dr. W. W. Dickenson, the superintendent of the then active zinc mine at Friedensville, observed a pinkish piece of rock thrown out of an exploratory shaft. It was about the size of a man's fist and found about 6 feet from the surface embedded in "ochery soil," evidently largely residual clay resulting from the solution of the limestones. It was close to a calamine vein and was first believed to have originated from either the dolomitic limestones or the zinc ores. Further investigations seemed to indicate that it was probably derived from a mass of allanite that had come from the crystalline gneisses that lie only a short distance to the north and had been transported as hillside wash. The first published description by Blake contains the following:

> "The specimen was about three inches in diameter and attracted my attention by its delicate pink color and peculiar structure, being an aggregation of thin plates and scales of a pearly luster, forming a light reticulated mass which was found to be highly crystalline on examination by a glass, and the crystals were apparently rectangular in form. . . .
>
> "The isolated plates or crystals appear transparent, and nearly colorless, but when the mineral is seen in mass it has a beautiful pink or rose color, and is not unlike that of peach blossoms." (Blake, 1853.)

Blake published a further description in 1858 (see bibliography), J. L. Smith discussed it in 1854, and Genth in 1857 and 1875. Genth gives additional data with analysis as follows:

> "The original specimen . . . consisted of an aggregate of small orthorhombic crystals in thin four-sided plates or minute tables, with beveled edges and a micaceous cleavage; it shows pearly lustre, and a delicate pinkish, grayish-white color. H = 2.5-3; sp.gr. = 2.605-2.666." (Genth, 1875.)

		Smith		*Genth*
Lanthana (and Didymia)	=	54.90	55.03	54.95
Carbonic acid	=	22.58	21.95	21.08
Water	=	24.09	24.21	(23.97)
		101.57	101.19	100.00

Eyerman tells of his unsuccessful search for other specimens in 1882. He says:

> "I have . . . always attributed this rare carbonate to the allanite locality, at Weber's, Lower Saucon, Northampton County, six miles from Easton, and notwithstanding the fact that my frequent exploratory work here has failed to disclose another allanite pocket, I still contend that this locality, and not Friedensville, was the source of the lanthanite." (Eyerman, 1911.)

Siderite ($FeCO_3$)

Siderite is common in many of the brown iron ore mines of the region, especially in the lower levels. It is light yellowish-gray to light brown and is usually in the dense amorphous form. Small crystals occur in some places.

Siderite ores were especially abundant in some of the Ironton mines, in Barber's mine south of Alburtis, and in some of the mines in the Saucon Valley. These are described in the chapter on iron ores.

Hydrozincite ($(Zn_5(OH,{}_6(CO_3)_2$)

Almost the only account of hydrozincite is the brief statement by Genth (1875) who says that "fine specimens have been found at Friedensville, Lehigh County, consisting of mammillated incrustations or porcelain-like and earthy masses."

Smithsonite ($ZnCO_3$)

Smithsonite is not one of the important zinc minerals in the Friedensville zinc ore deposits although specimens were noted from time to time.

> "It is found in small, but brilliant, white or grayish-white scalenohedra and in granular and globular masses at Friedensville, Lehigh County." (Genth, 1875, p. 161.)

SILICATES

Feldspars

The feldspars form a large and essential part of the gneisses and pegmatites of the county. In the pegmatites the crystals range up to an inch or more in size. They are also present in the Hardyston sandstones and in microscopic size in the limestones and other sedimentary rocks. Microscopic studies have shown the presence of orthoclase, microcline, microperthite (albite-orthoclase), albite, oligoclase,labradorite, and anorthite. More investigations will doubtless reveal the presence of still other members of the feldspar group than these mentioned. Orthoclase is most common in the gneisses of the region.

Garnet Group

Garnet is present as a rock-forming mineral in many of the metamorphic pre-Cambrian rocks of the South Mountain region. It is especially prominent in the Moravian Heigths gneiss and readily visible to the naked eye. Microscopic examination reveals garnets in other types of rocks, even in the limestones and slates. Almandite is the most common garnet but andradite and grossularite have been noted. Very few specimens of museum grade have been found.

The only special studies on the local garnets were made by Edgar F. Smith. His descriptions are quoted.

Almandite ($Fe_3Al_2(SiO_4)_3$)

At Mohr's magnetite mine in Upper Milford Twp., one-quarter mile from Shimersville, were found rather fine dark-red colored, imperfect dodecahedral crystals of this mineral. They occur in quartz and a granular limestone. The sp.gr. of well-selected material was 4.03, and an analysis of the same gave:

SiO_2	35.92	per cent.
Al_2O_3	19.18	
Fe_2O_3	4.92	
FeO	29.47	
MnO	4.80	
CaO	2.38	
MgO	3.70	
	100.37	

Directly south of the above locality upon the land of Mr. Yeakel, quite a large bed of garnet in very minute dark-red crystals has been discovered. It occurs with magnetite. (Smith, 1883.)

Andradite ($Ca_3Fe_2(SiO_4)_3$)

Near Hosensack Station in Lower Milford Twp., on the Perkiomen R. R., exists a second variety of garnet, found by Mr. E. F. Krauss, '84, in perfect dodecahedral forms of olive color—occasionally the red variety is observed—in a matrix of feldspathic rock. Specular iron ore often accompanies the garnet. The rocks in this region, lying in the most chaotic condition, appear filled with garnets, mostly in well-defined moderately translucent forms. An analysis of the yellow variety gave:

SiO_2	35.25	per cent.
Fe_2O_3	32.17	
FeO	.92	
CaO	30.80	
MgO	trace	
	99.14	

The specific gravity determined in two specimens was 5.05-5.27. (Smith, 1883.)

Garnet is present in some of the Triassic sediments of Lower Milford Township where baking has taken place by the intrusions of diabase. An occurrence of this kind is on the hill south of Hosensack. The garnet fills cavities formed by the solution of framents of limestone. Some of the lumps are almost two inches in diameter.

Mica Group

Mica is a common rock-forming mineral in both the highly metamorphosed pre-Cambrian crystalline rocks of the region and the slightly metamorphosed sedimentary strata. In the gneiss hills, in many places, the soil formed by the decomposition of the gneiss contains abundant mica flakes. The different varieties noted are described below.

Muscovite ($H_2KAl_3(SiO_4)_3$)

Muscovite in small crystals is a fairly common rock constituent of the Byram and Moravian Heights gneisses. In the pegmatites that cut these rocks, cleavage pieces from 3 to 4 inches in diameter have been found. An attempt was once made to work some of these pegmatites about 1½ miles southwest of Seidersville but without success.

In the sedimentary rocks two varities of muscovite have been noted, damourite(?) and sericite.

Sericite.—The Cambrian and Ordovician limestones of the county are mainly fairly high in silica and aluminous matter which represents mud that was washed into the Paleozoic sea when these limestones were forming. In the various movements that have taken place in the earth's crust since their deposition this argillaceous material has been metamorphosed to sericite. It forms glistening surfaces along the bedding planes and in many places is a conspicuous characteristic of these rocks. Also the mica which produces the fine cleavage in the slates of the county, is mainly sericite.

Damourite.—The Second Geological Survey of Pennsylvania referred to the mica occurring in the Paleozoic limestones of the State, formed from the muddy sediments mixed with the calcareous oozes, as damourite. The writer prefers to call this material sericite.

Pinite.—At the base of the Hardyston formation in many places in the county, but especially along the north side of the mountain between Bethlehem and Allentown, there is a light green amorphous, clay-like deposit up to a foot in thickness. This has been called serpentine (See note under this mineral). As a result of microscopic examination and chemical analysis, E. T. Wherry determined it to be pinite, a variety of muscovite. In a few places it has been colored red by the precipitation of red iron oxides from circulating waters.

Pinite is believed to be the metamorphosed ancient soil formed from the underlying gneiss and not removed before the deposition of the Hardyston sandstone.

Biotite ($H_2K(Mg,Fe)_3Al(SiO_4)_3$)

Biotite in small flakes is abundant as one of the constituents of some of the basic gneisses of the county; larger are pieces in some pegmatites.

AMPHIBOLE GROUP

Hornblende (Ca,Mg,Fe,Al, and Na silicate)

Hornblende constitutes a very important part of nearly all the gneisses and pegmatites of Lehigh County. It is rarely absent even in the lighter-colored gneisses and may constitute practically all the rock in the darker, more basic varieties. In several of the pegmatites some of the individual hornblende crystals may be over an inch in diameter. Specimens with crystal faces are rare.

Crocidolite ($NaFe(SiO_3)_2$)

Shortly after coming to this region in 1907, E. T. Wherry discovered a light blue mineral in several places in the gneisses between Center Valley and Vera Cruz. In places the blue color was so prominent, especially when the rocks were wet, that it could be noted in the rock along the roadside when driving by. Specimens were collected and the mineral roughly determined as an amphibole.

In 1913 Miss E. F. Bliss described the mineral as occurring in several places in Berks and Lehigh counties and identified it as glaucophane. In 1922 Wherry made a further mineralogical examination and concluded that it was crocidolite, not glaucophane. Both of these papers contain analyses and optical data. No one of the specimens described came from Lehigh County. Wherry states that this mineral is known to occur in about 50 localities.

The last paragraph of Wherry's paper is quoted.

> It is interesting to consider the mode of occurrence of the material: it is found as impregnations and coatings in gneissoid rocks of pre-Cambrian age, in diabase of Triassic age, and in sediments of the latter age intruded by the diabase. The gneisses thus impregnated are usually greatly shattered; the crocidolite not only fills the resulting crevices, but also replaces the original minerals of the gneiss. Replacement of hornblende was described by Mrs. Knopf (E. F. Bliss), and it may be added that the rocks, which usually contain considerable primary quartz where unaltered, are practically free from this mineral in extensively crocidolitized zones. Some of the silica has been redeposited, with the crocidolite, in the form of secondary quartz. The same phenomenon is noticeable in the replacement of these gneisses by sericite which is of frequent occurrence in the region, namely that the primary quartz is replaced more rapidly than the feldspar. This points to the deposition of the crocidolite, like the sericite, from hydrothermal solutions. The shattering of the crocidolitized gneisses is, in the experience of the senior writer, almost always connected with faulting of late Triassic date, and since the same mineral occurs in the late Triassic diabase and the sediments it has metamorphosed, the suggestion is here made that the hydrothermal solutions which deposited the crocidolite in the various occurrences came alike from the Triassic diabase magma. (Wherry, 1922.)

Actinolite and Asbestos ($Ca(Mg,Fe)_3(SiO_3)_4$)

Genth (1875, p. 69) says that "the so-called 'mountain leather' of a brownish color is found upon the limestone in the zinc mines at Friedensville."

F. R. Faux reports the presence of acicular actinolite crystals and actinolite asbestos in the baked Triassic conglomerate south of Hosensack.

PYROXENE GROUP

Augite ($CaMg(SiO_3)_2$ with Al and Fe

Augite is an important constituent of the gneisses of the district.

Diopside (Sahlite or Salite) ($CaMg(SiO_3)_2$)

Diopside has been recognized in some of the gneisses near Alburtis. It is fairly common in the pre-Cambrian metamorphic rocks.

Enstatite ($MgSiO_3$)

The microscopic examination of some of the gneisses of the region has shown the presence of enstatite.

Hypersthene ($(Fe,Mg)SiO_3$)

Hypersthene occurs as an important mineral constituent of some of the gneisses of the region and has been recognized by microscopic investigations.

Pectolite ($HNaCa_2(SiO_3)_3$)

Dr. Edgar F. Smith has studied pectolite from this region as follows:

> This mineral occurs in Lehigh County, Pa., upon limestone and intimately associated with stilbite. Its exact locality is Hosensack Station, on the Perkiomen Railroad. It usually consists of compact masses of acicular crystals, of a grayish color. When reduced to powder the material is woolly and adheres to the pestle. The specific gravity is 2.6. Several analyses were made by Mr. E. B. Knerr and myself, with the following result:
>
> | | | |
> |---|---|---|
> | SiO_2 | 55.17 | per cent. |
> | Fe_2O_3 | .80 | |
> | CaO | 30.00 | |
> | K_2O | .37 | |
> | Na_2O | 9.02 | |
> | H_2O | 4.63 | |
> | | 99.99 | |
>
> From what information we have obtained, it would seem that this is the first time that pectolite has been observed in the State. (Smith, 1885, p. 412.)

OTHER ANHYDROUS SILICATES

Allanite (complex Ca,Fe,Al,Ce silicate)

Allanite has been found in several places in the gneisses of South Mountain. So far as known it has not been reported from Lehigh County but must be present as it is present in the Northampton County gneisses nearby. It was first reported from Bethlehem by Genth in 1855 who published an analysis. Later a mass about 100 pounds in weight was found on the mountain south of the Lehigh University buildings. Since that time allanite has been noted in several localities in the vicinity of Bethlehem and Redington. It occurs in grains readily visible to the naked eye. Generally it is overlooked because of its resemblance to hornblende.

The analysis given by Genth (1875) represents the average of two analyses made by Peter Keyser. It is as follows:

SiO_2	33.31	CaO	11.28
Al_2O_3	14.34	MgO	1.23
Fe_2O_3	10.83	Na_2O	.041
FeO	7.20	K_2O	1.33
Ce_2O_3	13.42	H_2O	3.01
$(Di, La)_2O_3$	2.70		
			99.06
			Sp.gr.—3.491

Calamine ($H_2Zn_2SiO_5$)

Calamine is the most important ore mineral in the Friedensville zinc ores so far as mining operations have been carried on. It has been formed from sphalerite, which probably everywhere in that section underlies the calamine.

It is found in attractive small crystals or groups of crystals and in the massive form.

Eyerman (1889, p. 29) gives the following analysis of a specimen from the Ueberroth mine:

SiO_2	24.32
Fe_2O_3	2.12
H_2O	7.86
ZnO	65.05

Further data will be found in the chapter on Mineral Resources.

Epidote (complex Ca,Al,Fe silicate)

Epidote is a very common mineral in the light and dark-colored pre-Cambrian gneisses of Lehigh County. It has been formed from feldspars and hornblende. In some places, specimens of gneiss can be obtained in which approximately half the rock is epidote. It is common also in the pegmatites. Bands or streaks of almost pure epidote occur. Slickensided surfaces are commonly coated with a thin layer of epidote. In almost all cases the mineral is so fine-grained as to appear to the naked eye to be a homogeneous amorphous mass with a dull pistachio-green color, but small brilliant crystals, readily visible, have been observed, mainly along fault planes.

Sillimanite (Al_2SiO_5)

Wherry (1918) has reported abundant sillimanite in quartz-mica schists of Lehigh County. It "occurs in long slender prisms, mostly curved or bent slightly and in sub-parallel arrangement." In one locality, one mile west of Seidersville, it constitutes 35.1 percent of the rock. It is found mainly in the Moravian Heights formation. The sillimanite rock near Seidersville was quarried at one time in the belief that it was soapstone.

Titanite ($CaTiSiO_5$)

Dr. Edgar F. Smith described a find of titanite within the county:

> This mineral, rather rare in Pennsylvania, we have also found in Lehigh County, Lower Milford Township, about two miles distant from Hosensack Station. It occurs in the same region in which we observed an olive-colored garnet, previously described in this Journal, Vol. 5, No. 4. The titanite crystals are well defined, but not more than half an inch in length. They are associated with green pyroxene crystals. Their color is a dark brown. Specific gravity 3.45. The analysis of the above made by Mr. Knerr and myself gave:
>
> | | | |
> |---|---|---|
> | SiO_2 .... | 34.87 | per cent. |
> | TiO_2 .... | 43.41 | |
> | CaO .... | 21.75 | |
> | | 100.03 | |
>
> (Smith, 1885, p. 412.)

Tourmaline (complex Al,Mg,Fe,B,etc. silicate)

Tourmaline has been found in quartz or pegmatite veins cutting the gneisses of Lehigh County. Some of the pegmatites contain black crystals over half an inch long. Dr. Edgar F. Smith's description of Lehigh County occurrences is quoted.

> Mr. Benj. Sadtler, Jr., of this laboratory, while searching for corundum at Shimersville, picked up a piece of feldspathic rock, often found here, in which were imbedded three or four large and quite perfect, black crystals of tourmaline. Want of time prevents giving an analysis of the same.
>
> Dr. Henry K. Hartzell, of Allentown, also presented us with a hornblendic rock in which were beautiful brown tourmaline crystals, found near what is known as the Bethlehem Iron Co.'s mine on the Lehigh Mt., and not more than 1¼ miles northwest of Shimersville. A qualitative examination for identification is all that was made.
>
> On the mountain, two miles south of Allentown, occurs a vein consisting of a brownish-black mineral, which in appearance reminds one greatly of allanite, but the incomplete analysis given below would indicate otherwise, and probably mark it as another occurrence of tourmaline. Its surface in many places is covered by a reddish colored mineral as yet unexamined. The dip of the vein is about 66°. The analysis as far as made is:
>
> | | | |
> |---|---|---|
> | Loss upon ignition | 2.19 | per cent. |
> | SiO_2 | 39.41 | |
> | Al_2O_3 | 19.46 | |
> | Fe_2O_3 | 8.44 | |
> | FeO | 7.00 | |
> | CaO | 3.49 | |
> | MgO | 2.14 | |
> | B_2O_3 | 9.00 | |
> | Alkalies | undetermined | |
>
> (Smith, 1883, pp. 275-276.)

B. F. Buie has found rounded grains of yellow, brown, black, and green tourmalines fairly abundant in the insoluble residues of the Allentown limestones.

Zircon ($ZrSiO_4$)

Zircon has been observed in many of the pegmatites of the pre-Cambrian gneisses and in petrographic investigations as one of the accessory rock-forming minerals. On account of the small-sized grains it is only occasionally noted. One of the best places known to the writer is in the isolated gneiss hill along Little Creek west of Western Salisbury church. Careful search would doubtless add numerous new localities. Allen Heyl has found abundant zircon crystals on the south slope of South Mountain north of Vera Cruz. Some specimens are doubly terminated.

It has been found as one of the insoluble minerals of the limestones of the region and recognized in some of the alluvial sands.

The best description of the mineral in the county is that published by Edgar F. Smith many years ago.

> On the farm of Jacob Stine, Esq., Upper Milford Twp., about two miles south of Macungie, are found large quartz fragments distributed over the ground surface. When these are broken, minute crystals are observed here and there in them. Close examination showed these to be perfect forms of zircon—the prism with pyramid being quite distinct; the color of these microscopic crystals varied from a cinnamon to very dark brown. In some of the quartz fragments minute leaflets of graphite and pyrite crystals were seen accompanying the zircon. Enough qualitative tests were made to

identify the latter as such. Almost every piece of quartz examined contained one or more crystals of it. Their removal from the matrix was tedious and difficult. Scarcity of material prevented a quantitative examination. (Smith, 1883, p. 273.)

HYDROUS SILICATES

Allophane ($Al_2SOi_5.5H_2O$)

The mineral identified as allophane was commonly observed in the limonite mines when they were operating. Likewise Genth (1875, p. 107) reports that "at the Friedensville zinc mines, near Bethlehem, it is found in white botyroidal and stalactitic masses."

Edgar F. Smith had opportunity to study the minerals of Lehigh County during those years of iron mining activity and published the following description:

> About seven miles from Allentown, near the village of Ballitsville, are numerous iron mines (Ironton mines), in which from time to time have ben found white, mammillary and stalactitic incrustations upon the ore. In one of these mines a pocket was recently discovered, the inner side of which was completely covered with this coating. The latter has a mother-of-pearl-like appearance, and may be readily detached from the ore by means of a knife. Upon subjecting a portion of this material to a qualitative examination, the presence of water, alumina and silica was revealed. By strong hydrochloric acid, complete decomposition ensued. A quantitative examination yielded the following results:

H_2O	40.86	per cent.
SiO_2	21.39	
Al_2O_3	35.20	
$CaCO_3$ and $MgCO_3$ ...	1.96	
	99.41	

> Prof. Prime, in his report on the Geology of Lehigh Co. (DD, p. 43), mentions the occurrence of this mineral in some of the iron mines, but gives no analytical data. (Smith, 1883.)

Chloropal ($(Fe,Al)_2Si_3O_9.5H_2O$)

In 1932 while a shallow well was being dug on the lower slope of South Mountain a short distance north of Friedensville on the property of Alex. Males, a peculiar light green clayey substance was encountered with physical properties somewhat similiar to paraffin. The writer visited the locality, examined the material. and noted the occurrence. The material occurred about 15 feet from the surface mainly in the form of veins up to 2 inches in width cutting through the hillside wash of decomposed Byram gneiss. Some of the decomposed matter may have been *in situ*. The green substance in a few places also was disseminated through the residual sand and clay. After some study the mineral was determined to be chloropal.

Edgar F. Smith made a rather eleborate study of similiar material in 1883. Since the mineral is an unusual one his entire description is quoted.

> A little west of the preceding locality (Lehigh Mountain, near Mountainville) are rather extensive iron mines. Over the entire mountain-top holes are observed (dug, evidently in search of ore), and about these in the debris several students of this laboratory detected pieces of a yellowish-green colored mineral, so soft as to be readily impressed by the finger-nail. Before the blow-pipe the material, although infusible, gradually assumed a black

color and became magnetic; gave strong iron reaction and the silica skeleton. In a closed tube it yielded much water. Since the finding of the above specimens frequent visits have been made to this locality. On a recent trip, while examining some of the larger and deeper excavations, large pieces of the above mineral were noticed about six feet below the surface and overlying the iron deposit. The mineral varies somewhat in color from an olive to greenish-yellow. A number of analyses of the material brought in from time to time by various parties have been made, the results agreeing quite well and pointing to the mineral chloropal. The sp.gr. was found to be 2.033.

ANALYSES

	1	2	3	4	5	6
H_2O	19.61	19.79	18.65	20.79	20.45	19.09
SiO_2	40.20	40.81	42.31	41.16	41.41	42.79
Fe_2O_3	39.52	39.30	38.18	30.79	35.35	39.19
FeO	.40	—	trace	.21	—	—
P_2O_5	trace	—	—	—	—	—
MgO	trace	—	—	—	—	—
K_2O	trace	—	—	4.54	—	—
Al_2O_3	—	—	—	2.05	3.04	—
	99.73	99.90	99.14	99.54	100.25	101.07

	7	8	9	10	11
H_2O	19.27	19.31	19.31	17.71	19.36
SiO_2	42.37	41.35	41.13	43.54	43.00
Fe_2O_3	38.17	39.09	38.97	39.52	37.50
FeO	trace	—	—	—	—
P_2O_5	trace	—	trace	—	—
MgO	trace	—	trace	—	—
	99.81	99.75	99.41	100.77	98.86

1. Yellow, 2. Dark yellow, 3. Greenish yellow, 4. Yellowish green. This is the only instance where so much alkali was observed), 5. Yellowish green, 6. Light yellow, 7. Brownish yellow, 8. Same as 7, 9. As 7 and 8, 10. Brown variety, 11. Yellowish brown.

The mineral decomposes completely with hydrochloric acid. In all cases the specimens under examination were carefully freed of any adhering ferric oxide, and tested for ferrous oxide, phosphoric acid, calcium and magnesium oxides, and the alkalies. No trace of crystallisation is present. The mineral is earthy in appearance, smooth to the touch, and may be polished by friction.

Some specimens, almost white in color, have been found; one of these gave the following quantitative results:

H_2O	17.65	per cent.
SiO_2	44.52	
Fe_2O_3	11.04	
Al_2O_3	25.95	
MgO	trace	
K_2O	.94	
	100.10	

Halloysite ($H_4Al_2Si_2O_9+H_2O$)

It is probable that the investigations of clays made during the past few years may lead to new determinations of some of the argillaceous minerals found in this region. The discussion given here of halloysite and kaolin, and perhaps chloropal, are therefore regarded as merely tentative and the statements quoted are of the character of historical material.

Genth (1875, p. 122) says that "a mineral resembling halloysite is found in compact porcelain-like masses at the zinc mines at Friedensville."

Gordon (1922, p. 127) considers the clay called "sauconite" as a variety of halloysite, but here it is discussed as a variety of kaolin, following Genth.

Kaolin ($H_4Al_2Si_2O_9$)

Kaolin as used here is a general designation of the clay minerals. In the decomposition of feldspar in the gneisses and pegmatites much kaolin has been formed. In the change to kaolin the gneiss crumbles and most of the resulting products are removed by erosion. However, in places along the hillsides, the rotten rock, consisting mainly of kaolin and quartz, is not removed and may be ten to twenty feet deep. The kaolin is commonly stained by iron oxide. In no place in Lehigh County has it been found practicable to separate the kaolin commercially.

Prof. Roepper, the man who first recognized the zinc minerals at Friedensville, studied a variety of clay found there. The following discussion by Genth presents Roepper's ideas.

> I have to mention, however, sveral peculiar clays, which have been found in this State.
>
> The first occurs at the Ueberroth Zinc Mine near Friedensville, Lehigh county, where it has been discovered by Prof W. Th. Roepper, who named it "Sauconite," and kindly furnished me with the following description and analyses. It has also been analyzed by John M. Blake (Dana's Mineralogy 1868, 409).
>
> Apparently amorphous, fracture conchoidal; streak brown and shining; colors buff, ochre-yellow, brown, dark gray and white; translucent on thin edges; translucency increased by wetting. When thrown into water emits a crackling sound. H = 1.5; sp.gr. = 2.66-2.70.
>
> The following varieties have been analyzed by Roepper: *a.* pale yellowish-white; *b.* ochre-yellow (after having been dried during one hour at 105°C.); *c.* Blake analyzed a pale-yellow variety:

		a.	b.	c.
Silicic acid	=	48.94	46.45	41.36
Alumina	=	10.66	7.41	8.04
Ferric oxide	=	3.85	14.28	9.55
Zinc oxide	=	26.95	22.86	32.24
Magnesia	=	....	) 0.97	1.02
Lime	=	2.42	)	....
Potash	=	....	....	trace
Water	=	7.06	6.73	7.76
		99.88	98.69	99.97

> Like all similar minerals, the composition is somewhat variable, owing in part to accidental admixtures, and a replacement of one isomorphous substance by another.
>
> Allowing in the first analysis for a mechanical admixture of 3.45 per cent. of silicic acid (quartz), the oxygen ratio of zinc-oxide and lime (RO), to alumina and ferric oxide (R_2O_3), to silicic acid and water are = 1:1:4:1, corresponding with the formula: $3(RO,SiO_2)+R_2O_3,3SiO_2+3H_2O$.
>
> I believe the sauconite to have as good a claim to be a distinct mineral species, as nine-tenths of the amorphous species, acknowledged as good. (Genth, 1875, pp. 120-121.)

The clays of the county are further described in the chapter on the Mineral Resources.

Serpentine ($H_4Mg_3Si_2O_9$)

Locally some altered igneous rocks in the region may properly be classed as serpentine. The occurrence of this mineral within this county may well be ignored.

A greenish mineral found at the base of the Hardyston formation and determined to be pinite has been mistaken for serpentine. Genth evidently had this in mind when he says:

> Outside of the serpentine range, common serpentine has been observed in peculiar varieties which deserve fuller investigation: in Potsdam sandstone, a short distance north of Bethlehem etc. (Genth, 1875, p. 115.)

Stilbite ($((Ca,Na_2)Al_2Si_6O_{16}.6H_2O)$)

The only known occurrence of stilbite in the county is that described by Edgar F. Smith. It is quoted.

> This mineral was first found in Lehigh county, by Mr. E. F. Kraus, upon a limestone in the orchard of Mr. Jacob Schell, near Hosensack station. The specimens are in the form of large globular radiating concretions. Sp. gravity, 2.21.

Analysis

SiO_2	55.31	per cent.
Al_2O_3	14.88	
Na_2O	1.66	
H_2O	18.47	
	99.32	

(Smith, 1883, p. 277.)

Eyerman (1889, p. 32) points out that an error by the printer resulted in the omission in the above analysis of CaO.... 9.00 per cent.

PHOSPHATES

Wavellite ($Al_3(OH,F)_3(PO_4)_2.5H_2O$)

Analyses of the limonite ores of the region show the presence of phosphorus. In most cases the phosphorus mineral present is not apparent. In a few instances, however, beautiful patches of radiating white wavellite crystals can be discovered along cracks or joints if the ore or associated ferruginous rocks are broken. All the occurrences known to the writer are in those ore mines in the belt of the Hardyston formation. Some fine specimens were collected by the writer at the pyrite prospect shafts on the slope of the mountain southeast of Wilbur.

The complete descriptions by Smith of the Macungie location are quoted.

> The specimens of Wavellite are from the neighborhood of Macungie, Lehigh Co., Pa. They present radiating nodules on limonite; their color is white. These crystals were considered to be calamine, and on this account we experienced some difficulty in ascertaining the locality. Indeed, we were obliged to show qualitative proof of the absence of zinc to the parties interested, before being made acquainted with the history of the specimens. Our analyses were made of some of the well-defined crystals. The method of analysis pursued, was that described by Dr. F. A. Genth, in Am. Journal of Science, etc., II Vol. 23, p. 423.

Analysis

Al_2O_3	36.66	per cent.
P_2O_5	34.14	
H_2O	28.32	
Fl	trace	
Limonite	0.60	
	99.72	

Chemical Laboratory of Muhlenberg College, Allentown, Pa., March 3, 1882. (Smith and Thomas, 1882, p. 231.)

Not more than a quarter of a mile from the above locality (two miles south of Macungie, Upper Milford Township) and upon the same farm, were found the beautiful crystals of wavellite described by Dr. N. W. Thomas and the writer, Proceedings of American Philosophical Society, March 17, 1882. The first specimens of this mineral were noticed as occurring on limonite; since the publication of the preliminary notice we have obtained, through the liberality of Mr. Stine, a number of specimens lying upon or disseminated through a jasper-like rock which overlies the iron bed. The adjacent land is covered with rock of this character. Mixed with the iron is much pyrolusite. At present the shaft, in which the most beautiful wavellite was found, is filled with debris. From the quantity of the mineral found at first, and the many points at which it was observed prior to the caving-in of the surface, we may reasonably expect to yet obtain handsome specimens. It usually occurs in beautiful, colorless, radiating nodules on the limonite or jasper-rock.

Accompanying the wavellite and frequently upon the same specimen were observed nodular, light clay-like forms; sometimes, too, very dark nodules. Some of these revealed no definite radiating structure, while in others this was quite prominent; yet all trace of the white needles of wavellite had completely disappeared. In several instances these nodules were larger than a pigeon's egg. To learn their composition, specimens of both light and dark varieties were analysed. Light variety: sp.gr. 2.5.

H_2O	19.37	per cent.
SiO_2	32.42	
Al_2O_3	23.19	
Fe_2O_3	3.82	
P_2O_5	19.19	
CaO	1.00	
MgO	.47	
	99.46	

Dark variety, sp.gr. 2.40. Analysis:

H_2O	26.29	per cent.
SiO_2	6.52	
Al_2O_3	29.37	
Fe_2O_3	15.61	
P_2O_5	22.52	
	100.31	

(Smith, 1883, pp. 273-274.)

URANATES

Uraninite

Dr. Edgar T. Wherry has recognized small grains of uraninite at the Vera Cruz molybdenite locality described on a previous page.

SULPHATES

Goslarite ($ZnSO_4.7H_2O$)

Hydrous sulphate of zinc or white vitriol has the mineralogical name goslarite. It is found as a result of the oxydation of zincblende in incrustations and fine needle-shaped, white crystals at Friedensville, Lehigh County. It is a rare mineral. (Genth, 1875, p. 149.)

Melanterite ($FeSO_4.7H_2O$)

Wherever pyrite is exposed to oxidizing conditions, melanterite is apt to be found. It has been noted at the pyrite prospect between Mountainville and Emmaus and about some of the limonite mines where pyrite occurs. It has been especially noticeable at the old mine north of Breinigsville.

GEOLOGIC HISTORY

By Benjamin L. Miller

More than a billion years of history is recorded in the rocks of Lehigh County and it is the duty of the geologists to decipher these records. The task is a tremendous one and is at present only in the preliminary stage. Many of the main events are dimly understood, especially those concerned with great upheavals or revolutions, but there are great gaps in our knowledge. The untangling of happenings in the dim past is made difficult and in some instances impossible by the destruction of much of the record. One may liken the work of the geologist to that of the historian who endeavors to write a consecutive history of mankind from a badly mutilated volume. If he can find in some other library another copy of the same book, perchance the missing portions of one volume will be found in the other one. By gradually extending his researches to other libraries where imperfect copies are preserved, eventually the gaps may be lessened and the story pieced together. Geologists work in a similar manner. Gaps in the recorded history existing in one locality may be filled in by data secured in another region.

Nature has been engaged alternately in construction and destruction; records have been written in the rocks and later in large part erased by the natural agents of weathering, erosion and metamorphism. Some records are transcribed in a language that is unintelligible except by the slow process of trial and error. An interpretation that seems reasonable at one period may be relegated to the discard when additional facts are obtained. Scientists have been accused of inconsistency when, without being conscious of any ''loss of face,'' they throw aside their earlier explanations and advance new ones. Lesley expressed the idea in the following sentence.[1] ''Geologists should be consistent; but what can poor geologists do when Nature is the mother of inconsistency.'' Little progress can be made unless interpretations (hypotheses and theories) are formulated to explain the facts accumulated. These are then tested by all the additional information that can be secured. Thus, the explanation may be strengthened, modified or thrown aside for a newer and better interpretation. Only in this manner have our natural sciences advanced.

The methods used by the geologist are those that have developed during the past century. By studying the natural processes of destruction and construction, and observing their effects and results, keys for deciphering the events recorded in the rocks and in the structural and physiographic features have been obtained. In the story of past events in this region, only the barest outline can be presented at this time. Gaps will be filled by future workers.

---

[1] Lesley, J. P., Second Geol. Survey of Pennsylvania, Final Rept., vol. 2, p. 891.

The events of each era and period have been described somewhat in the descriptions of the different formations. It remains therefore to piece together the records. Due to the fact that the pre-Cambrian events are so different from those of later times it is fitting that Dr. Fraser tell the geologic story of that distant time.

Pre-Cambrian History

By Donald M. Fraser

With the assumption that the Franklin limestone is the oldest formation in the district, the earliest recorded event in Lehigh County would be the deposition of a series of carbonate rocks. Little else is known regarding this earliest time. Following the accumulation of the limestone, or possibly more or less contemporaneously with it, clastic sediments containing carbonaceous material were deposited. The present quartz-graphite member of the Franklin formation is the remnant of this depositional period which surely resulted in a fairly extensive sedimentary formation at the time of its accumulation.

With the changing conditions of deposition the sediments from which the present Moravian Heights formation has been derived were laid down. These were quartzose sediments but were more argillaceous than the clastic material associated with the Franklin formation. Again, on the basis of the present distribution of small areas of the Moravian Heights throughout tens of square miles, it is assumed that the original sediments were of considerable extent. They may well have covered several hundred square miles.

The next formation is the Pochuck gneiss. This basic rock, in the past, has been considered as of possible partial sedimentary origin and in part to have been derived from the metamorphism of a gabbro or diorite-gabbro type of igneous material. The present writer regards the Pochuck to be entirely of igneous origin. It may have been formed by the metamorphism of a gabbroic type of rock but it could also have been derived from the metamorphism of a series of andesite and basalt lava flows. Whichever may prove to be the correct interpretation, the next event in the district following the accumulation of the Franklin and Moravian Heights sedimentary formations was igneous activity. Either the present Pochuck gneiss material was introduced by intrusions of a basic magma or by the extravasation of lavas.

The earliest of these three formations has been tentatively assigned to Archean time and the later two to the Huronian. They are all of patchy occurrence and with the exception of the Pochuck have very small areal extent.

Later Proterozoic time probably saw extensive erosion and igneous invasion of an acid type of magma. The group of rocks known as the Byram gneiss ranges from what is considered to be typical Byram (a quartz-microcline microperthite rock) to quartz monzonite types. Associated with these are numerous pegmatites. The entire series has been mapped as Byram because more detailed study and mapping than that possible on the scale of the map used here, will be necessary to delineate the various facies. In the sequence of pre-Cambrian events, therefore, we are able to state only that during later Proterozoic time extensive granitic intrusion prevailed in the area under discussion. That this intrusion was in part deep-seated is evidenced by the highly irregular and injected and contorted nature of the contact between the Byram and Pochuck. It follows, therefore, that after the granitic invasion there was very extensive erosion before the surface upon which the Cambrian rocks were deposited could have been exposed. Proterozoic magmatic activity continued into early Paleozoic time or repeated invasions of magmatic material may be suggested with the later activity continuing into at least Lower Paleozoic time. The evidence for this is the occurrence of quartz-feldspar dikes in the Hardyston sandstone near its contact with the pre-Cambrian granitic material. With the dying stages of magmatic action existent into Lower Paleozoic time, at least some of the quartz veins found in the Cambrian and Ordovician rocks may well be of magmatic origin.

Cambro-Ordovician History

The Paleozoic history of this section recorded in the rocks begins with the deposition of the Hardyston sandstone in the Lower Cambrian period. There is, however, a big gap between these deposits and the underlying crystalline rocks of the pre-Cambrian.

The Hardyston sandstones, wherever contacts have been observed, rest unconformably upon greatly metamorphosed gneisses. An examination of these basal rocks shows that they attained their present character of coarse-grained and banded crystalline rocks while deeply buried beneath enormous loads of other rocks. The Byram gneiss, which is the most common type of rock on which the Hardyston rests, was originally a granite and it is now generally recognized that granites are igneous rocks that cooled at considerable depth beneath the surface. The gneissic banding, which the Byram shows, is believed to have been developed as the result of subsequent excessive compression and resultant heating such as can also take place only at great depth. These features must have been acquired long before the Hardyston strata were laid down since these deposits show positively that they have never been subjected to such metamorphic agencies. The conclusion, therefore, seems certain that a long period of erosion, during which a great thickness of pre-Cambrian rocks was removed, preceded the opening of Cambrian deposition. One can only guess at the depth of surface rocks carried away but it appeals to the writer that the amount was upwards of a thousand feet and probably several thousand feet. It is pure conjecture as to where the eroded material was transported and deposited as no evidence bearing on this problem is now known. Here, therefore, is one of the great gaps in our history of past events in the region.

The earliest recorded event in the Paleozoic history of the district is the depression of the entire region as well as extensive areas both to the northeast and southwest. The entire Appalachian region, which had presumably long been an area of erosion, gradually sank beneath the waters of a great southeasterly advancing inland sea.

Beginning with Hardyston time and continuing throughout the entire Paleozoic era, all geologists believe there was a large continental land mass, to which the name "Appalachia" has been applied, from 100 to 300 miles or even more in width, that paralleled the present Atlantic shore line. At times the northwest margin of this land perhaps lay only a short distance to the southeast of what now constitutes Lehigh County. At other times, the shore may have been several scores of miles away.

The inland sea covered all of the present Appalachian province. It varied from time to time in size and shape owing to movements or warpings of the earth's crust. In this sea, which appears to have always been comparatively shallow, practically all the materials now constituting the sedimentary rocks of Lehigh County were accumulated on a gradually sinking bottom.

When the depression of the area occurred, there was probably a fairly deep cover of soil and rotten rock over the land. The waves of the advancing Cambrian sea seem to have removed most of this surficial cover inasmuch as the Hardyston in most places rests on fresh unchanged gneisses. Locally, however, a thin band of a peculiar rock is found at the contact, which is believed to be an old soil. It has now been altered to a dense, fine-grained, light green rock that has been called pinite. It is never more than a few feet thick and can seldom be recognized over any extensive area. It is developed in several localities in Lehigh County. It is questionable as to whether this material should be included in the Byram or in the Hardyston. Inclusions of angular vein quartz fragments link it with the former, and occasional rounded pebbles suggest the latter reference.

The lowest strata of the Hardyston are conglomeratic in several places but not everywhere; occasional pebbles are more than an inch in diameter. These coarser sediments constitute a basal conglomerate that was formed either near the mouths of streams or where shore currents were reasonably strong. They probably formed near the shore as the advancing sea transgressed. They also indicate that the land mass from whence the pebbles were derived was fairly high and thus furnished stream gradients sufficiently steep to transport the pebbles.

Probably owing to the southeasterly retreat of the shore line by the sinking of Appalachia, coarse pebbles were carried into this region for only a short time. Most of the deposits of Hardyston time were sands, generally fairly fine. Crystalline rocks from Appalachia were breaking up without the complete decomposition of the feldspars, and numerous grains of fresh orthoclase were deposited with the quartz grains and kaolin. The arkosic character is a prominent feature of the Hardyston sandstones.

A progressive change in the sediments from sands to shales and calcareous oozes took place and we pass from the Hardyston to the Tomstown sediments. The Tomstown and also the overlying Allentown formations contain occasional fine sandstone lenses, indicating that unusual conditions, probably freshets or floods, once in a great while brought some sands into the region. Generally, however, only the finest land-derived material came in. This indicates the lowering of Appalachia to the extent that the streams entering the sea carried only the finest material in suspension and these only at certain times. They brought calcareous matter in solution and this was precipitated on the ocean bottom either by purely chemical processes or by the agency of minute organisms, particularly bacteria. Probably both methods were operative. The rocks themselves present no evidence as to the method by which the calcareous matter was taken out of solution.

During Allentown time, less sand and mud entered the sea although shaly layers and a few fine sandstone lenses indicate that occasionally terrigneous matter came into the sea from Appalachia. The life of the Allentown seas was not varied, so far as local evidence indicates. The only abundant fossils are the calcareous algæ, *Cryptozoa,* which are fairly abundant. In places they withdrew from the sea water and built into their structures sufficient calcareous matter to form deposits several feet in thickness.

Occasionally during both Tomstown and Allentown time the sea was so shallow that at low water, perhaps low tide, the fine muds were exposed to the drying action of the sun and developed mud cracks as they contracted in drying. These are preserved in many localities. Ripple marks and oolites also indicate shallow water.

When the deposits of the Tomstown and Allentown formations were accumulating, the oozes contained much magnesia, and these limestones are prevailingly dolomitic. In part the magnesia may be secondary but it is regarded as largely original.

In the succeeding interval of time, when the Beekmantown limestones were formed, the calcareous oozes at times contained very small quantities of $MgCO_3$ and we therefore have in this formation the alternations of high- and low-magnesian strata.

Throughout Tomstown and Allentown time the seas had been generally clear of land-derived sediment except at occasional brief periods. The Beekmantown sea was even clearer and mud seldom came into it. This probably means that Appalachia was so low as to yield to the sluggish streams a minimum amount of mud in suspension and practically none of it was carried into this region. An alternative interpretation is that the nearest land mass was more distant.

Shell-fish were more abundant during the Beekmantown but, as indicated by the rarity of fossils, relatively sparse in this section, especially as compared with some other regions in the Appalachians.

Following the formation of the Beekmantown there was a short break in deposition, as shown by an unconformity between the Jacksonburg and the Beekmantown. Deposition was resumed and the seas became increasingly muddy and the $MgCO_3$ decreased. The interval represented by the deposition of the lower member of the Jacksonburg formation was a time when high-calcium oozes accumulated. It was followed by the deposition of much terrigenous mud which was mixed with the calcareous oozes. These constitute the upper member of the Jacksonburg. These argillaceous low-magnesian limestones are the most valuable deposits of the county, as they have furnished the material for the extensive portland cement industry of this region.

Fossils are much more abundant in the Jacksonburg than in any of the other sediments of the region, thus indicating more favorable conditions for life and growth. The animals seem to have been mainly near-shore forms and their skeletons were broken by wave action to such an extent that the fossils are mainly fragments. Crinoids were abundant but only the disarticulated plates are preserved.

Increasing muddiness of the seas and the practical disappearance of calcareous precipitates resulted in the deposition of the argillaceous Martinsburg strata. Carbonaceous matter is abundant in these dark gray or black sediments. Its source is problematical but may have been marine plants. Graptolites may have contributed part of the carbonaceous content. Frequent changes in the character of the sediments has resulted in the production of the light and dark layers that are called ribbons by the slate operators. These are most prominent in the basal member of the Martinsburg.

The sandy member represents a period during which considerable sand entered the sea in this section. Likewise, more calcareous matter was precipitated and these sandstones, when fresh, effervesce freely when hydrochloric acid is applied.

For about 200 million years, from early Cambrian to Upper Ordovician, deposition had been going on almost continuously in this region, and sediments had accumulated to a thickness of 7,500 to 10,000 feet. The continent of Appalachia and the inland sea underwent modification many times but there were few breaks in the process of deposition. A minor one occurred at the close of the Beekmantown and another one at the close of the Jacksonburg.

Taconic Disturbance [1]

After Martinsburg deposition there was a marked disturbance in this region, so great that it has sometimes been called the Taconic Revolution. It is named from the Taconic Mountains of western Massachusetts where it was first studied. How much of the complex folding and faulting of this region is due to this period of compression and uplift and how much was produced by later movements of the Appalachian Revolution is still a matter of argument and discussion. The writer holds the belief that a large part, perhaps the major portion of the rock folding of this region, was produced at the close of the Ordovician. He is inclined to the belief that the slaty cleavage of the Martinsburg was chiefly produced at this time. The pressure seems to have come from the southeast.

A period of erosion followed the disturbance but the amount of material then removed can not be determined with any accuracy.

Silurian and Later Paleozoic History

After a marked erosion period, during which time all of the Northampton County area was above water, the region again sank beneath the waters of the vast inland sea. The deposits then made constitute the Tuscarora conglomerates and sandstones that form the northern boundary of the county. The basal conglomerate layer exposed in Lehigh Gap rests unformably upon the eroded edges of the Martinsburg slates. There is a difference of thirteen degrees between the bedding planes of the two formations.

The coarse pebbles of the Tuscarora, many more than an inch in diameter, furnish evidence of strong currents and probably steep slopes of the land mass to the southeast that furnished the material.

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[1] Miller, B. L., Taconic Folding in Pennsylvania: Geol. Soc. Am. Bull., vol. 37, pp. 497-511.

Later sedimentary Paleozoic history is not preserved in Lehigh County, although it is probable that some and perhaps all of the later Silurian, Devonian, Mississippian and Pennsylvanian formations exposed in the regions to the northwest in neighboring counties may have once extended into this county. If so, they have been entirely removed by subsequent erosion.

Appalachian Revolution

The Paleozoic era in the Appalachian region ended by one of the most profound periods of uplift, folding and faulting that has ever taken place. Thousands of feet of rocks were folded by compressive forces coming from the southeast as though they were mere sheets of paper. These movements, added to those that deformed the earlier strata at the close of the Ordovician, made the complex and baffling structures so characteristic of Lehigh County.

Triassic History

The next recorded event is in the southern part of the county. A slowly subsiding basin twenty to thirty miles in width extending in a northeast-southwest direction entirely across the southeastern part of Pennsylvania. Into this basin thousands of feet of sediments were deposited. The deposits are mainly shales, shaly sandstones and soft sandstones with a prevailing red color. In that portion of the Brunswick represented in Lehigh County coarse conglomerates are more common and indicate the occurrence of torrential streams. Some of the pebbles are limestones that seem in part to have come from distant points. The conglomerates have been attributed by some to the deposits formed at the mouths of streams.

Toward the close of Triassic sedimentation there were intrusions and surface outflows of basic igneous matter that now form our traprock hills. This is the last time that igneous action has taken place in Pennsylvania.

Glacial History

In the Pleistocene period this region was invaded by a lobe of the great ice sheet that originated in eastern Canada. Although the erosional and depositional work of the ice profoundly modified much of the New York and New England regions, this section reveals few evidences of its work. It passed through the valley, probably covering practically all the area between Kittatinny (Blue) Mountain and South Mountain, with a slight advance into the Saucon Valley. The ice in this advance seems to have been thin so that the amount of erosion was trivial. Deposition throughout most of the county was of little consequence except in some depressions, such as old stream valleys and solution holes in the limestones.

Whether the deposits formed during the greatest advance of the ice should be considered as belonging to the Illinoian Ice Sheet as claimed by Leverett or the preliminary advance of the Wisconsin Ice Sheet as advocated by Williams is a problem that has long been in question and is discussed elsewhere. The terminal moraine between Wescosville and Trexlertown represents the greatest advance of ice of the Illinoian or the early stage of the Wisconsin.

Physiographic History

The physiographic record has been discussed in the chapter on Physiography, so only a brief summary is given here.

The existing topography is the result of erosion and minor deposition with alternate peneplanations and uplifts that have been at work in this region ever since the Appalachian Revolution. Decomposition, rain wash and streams have been the tools with which Nature has carved the existing hills and valleys.

Presumably, the period of Schooley peneplanation in Tertiary time saw the entire area reduced to a featureless low-lying region with all elevations due to earlier earth movements destroyed. From this surface the present differences in elevation have been developed, following an uplift that revived the agents of erosion. Those areas with the most resistant rocks, such as the siliceous sandstones of Kittatinny (Blue) Mountain, have suffered least and now stand highest, whereas the softer and more soluble rocks, such as the limestones, constitute our valleys.

If this region maintains its present elevation with reference to sea level, the destructive processes of erosion will continue to modify the topography. The tendency will be to reduce the existing differences and produce even more subdued scenery, with the ultimate reduction to another base level plain. Under present conditions this may result in from one to three million years. From what we know of the earth's instability, one may well question whether before that time there may not be interruptions or modifications in the erosive process caused by deformations of the crust.

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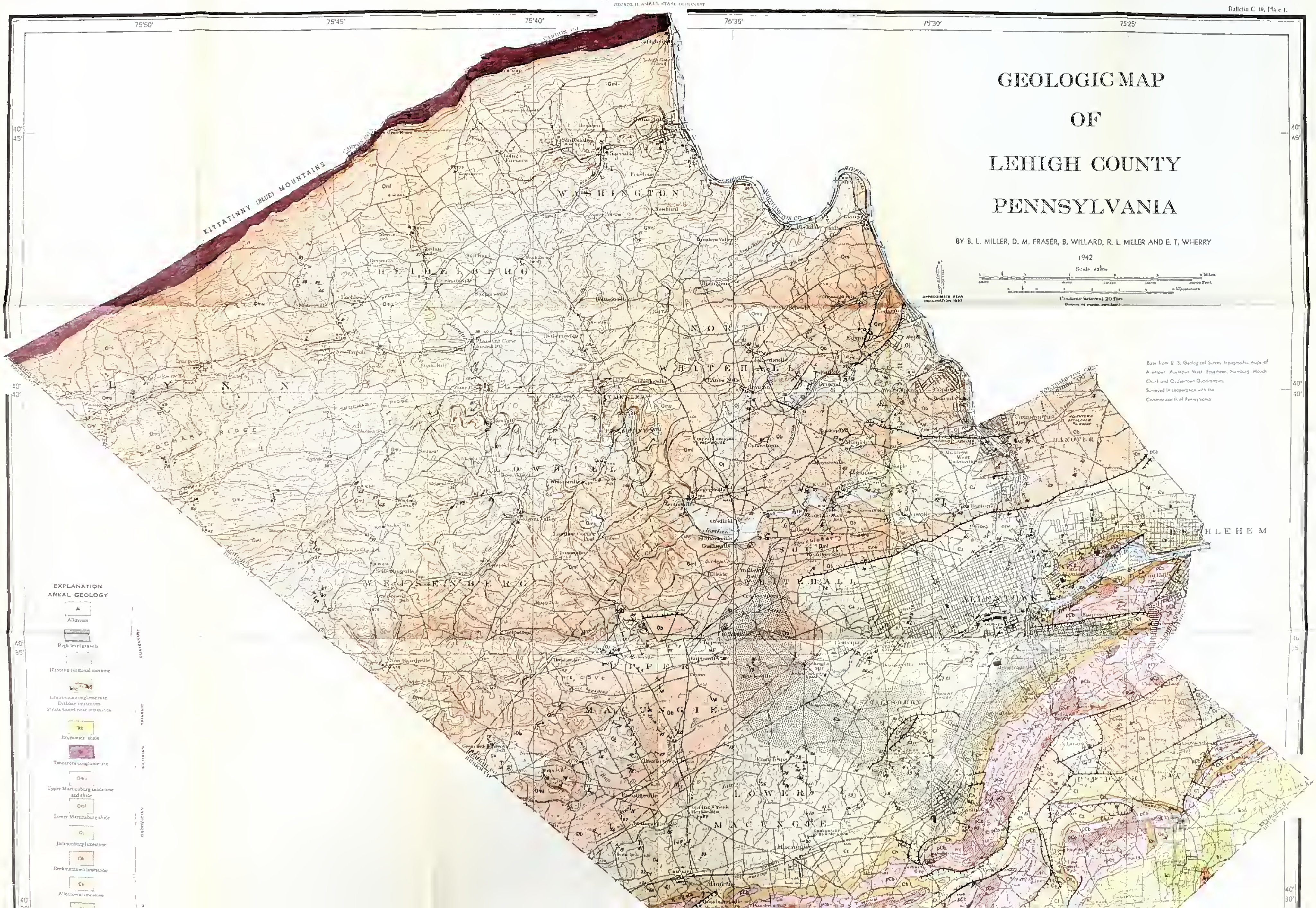
William S. Livengood, Jr. Secretary
TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, STATE GEOLOGIST



GEOLOGIC MAP
OF
LEHIGH COUNTY
PENNSYLVANIA

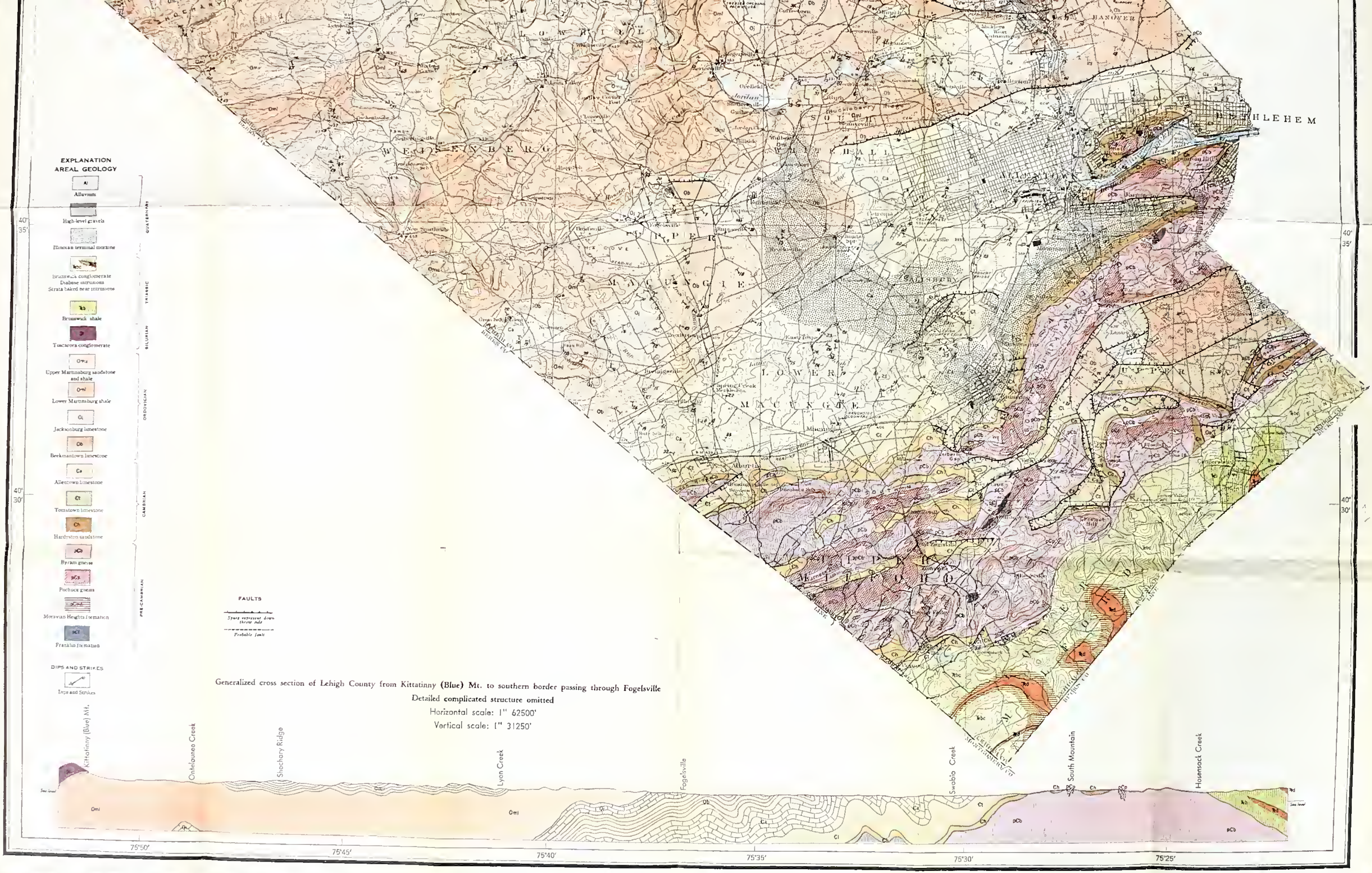
BY B. L. MILLER, D. M. FRASER, B. WILLARD, R. L. MILLER AND E. T. WHERRY

1942

Scale $\frac{1}{62500}$

Contour interval 20 feet
Datum is mean sea level

Base from U. S. Geological Survey topographic maps of Allentown, Allentown West, Boyertown, Hamburg, Mauch Chunk and Quakertown Quadrangles.
Surveyed in cooperation with the Commonwealth of Pennsylvania



Generalized cross section of Lehigh County from Kittatinny (Blue) Mt. to southern border passing through Fogelsville

Detailed complicated structure omitted

Horizontal scale: 1" 62500'

Vertical scale: 1" 31250'

PENNSYLVANIA DEPARTMENT OF INTERNAL AFFAIRS
William S. Livengood, Jr. Secretary
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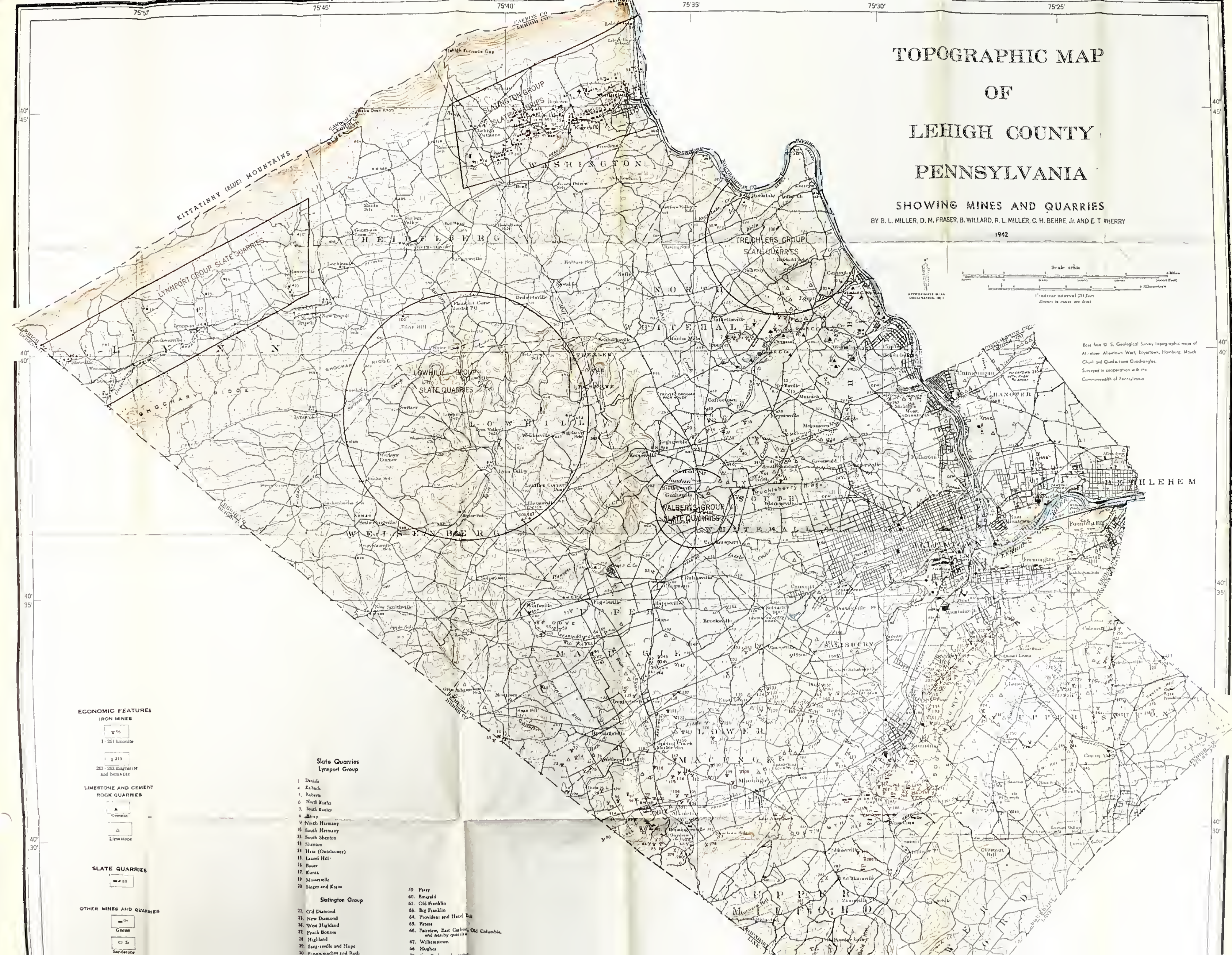
Bulletin C 39, Plate 2.



TOPOGRAPHIC MAP
OF
LEHIGH COUNTY
PENNSYLVANIA

SHOWING MINES AND QUARRIES

BY B. L. MILLER, D. M. FRASER, B. WILLARD, R. L. MILLER, C. H. BEHRE, Jr. AND E. T. WHERRY

1942

Base from U. S. Geological Survey topographic maps of Allentown East, Allentown West, Boyertown, Hamburg, Mauch Chunk and Quakertown Quadrangles.
Surveyed in cooperation with the Commonwealth of Pennsylvania

ECONOMIC FEATURES

IRON MINES

1 - 261 limonite

262 - 282 magnetite and hematite

LIMESTONE AND CEMENT ROCK QUARRIES

Cement

Limestone

SLATE QUARRIES

OTHER MINES AND QUARRIES

Gneiss

Sandstone

Slate Quarries

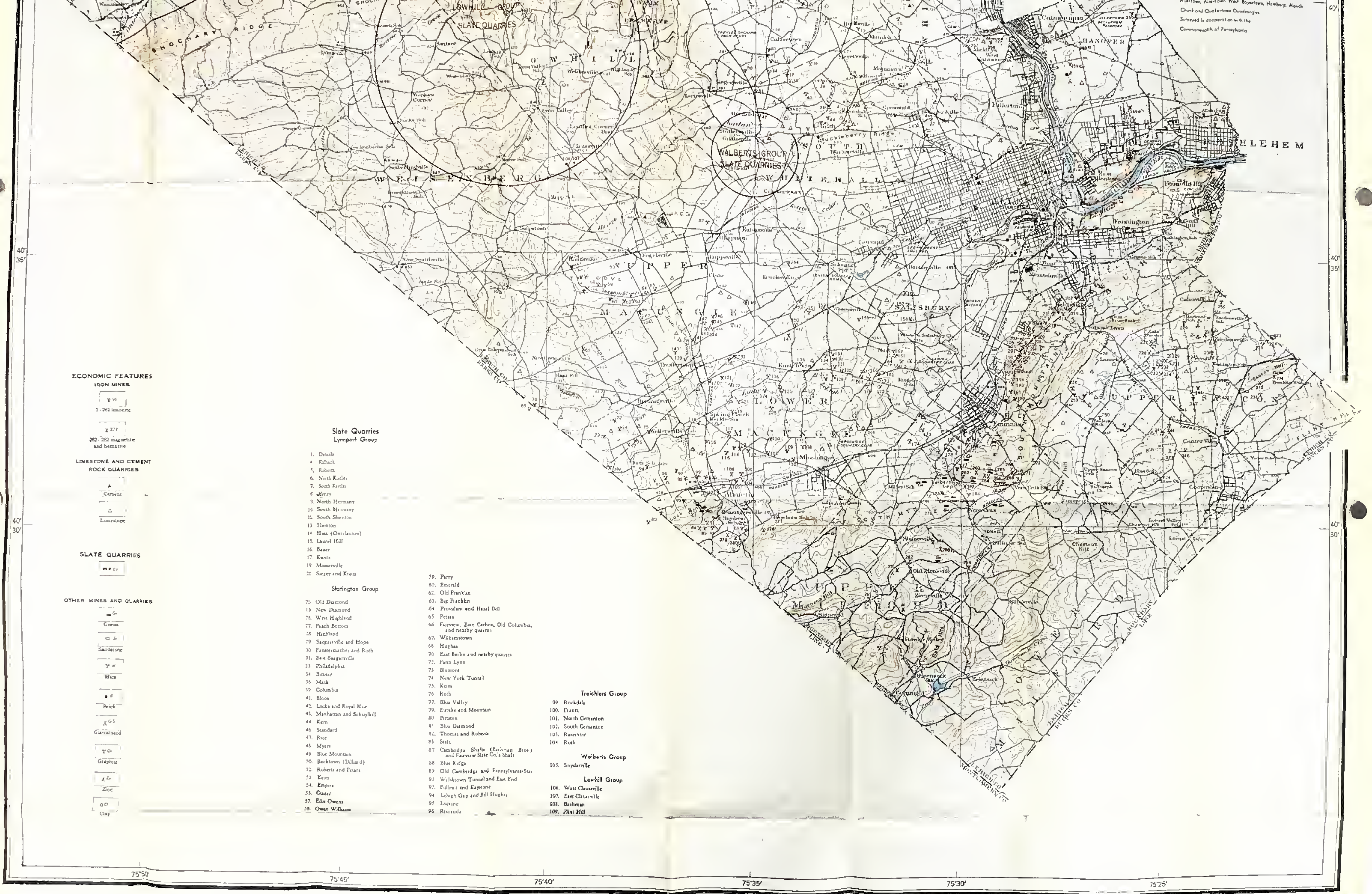
Lynnport Group

1 Daniels
4 Kalbach
5. Roberts
6 North Kistler
7. South Kistler
8 Henry
9 North Hermany
10. South Hermany
11. South Shenton
13. Shenton
14 Hiss (Ontelaunee)
15. Laurel Hill
16 Bauer
17. Kuntz
19 Mosserville
20 Sieger and Kraus

Slatington Group

21. Old Diamond
23. New Diamond
26. West Highland
27. Peach Bottom
28 Highland
29. Saegersville and Hope
30 Fenstermacher and Roth

59 Parry
60. Emerald
62. Old Franklin
63. Big Franklin
64. Provident and Hazel Dell
65. Peters
66. Fairview, East Carbon, Old Columbia, and nearby quarries
67. Williamstown
68 Hughes



Slate Quarries

Lynnport Group

1. Daniels
4 Kalbach
5. Roberts
6. North Kistler
7. South Kistler
8 Henry
9. North Hermany
10. South Hermany
12. South Shenton
13 Shenton
14 Hess (Ontelaunee)
15. Laurel Hill
16. Bauer
17. Kuntz
19 Mosserville
20 Sieger and Kraus

Slatington Group

22. Old Diamond
23 New Diamond
26. West Highland
27. Peach Bottom
28 Highland
29 Saegersville and Hope
30 Fenstermacher and Roth
31. East Saegersville
33 Philadelphia
34 Bittner
36 Mack
39 Columbia
41. Bloss
42. Locke and Royal Blue
43. Manhattan and Schuylkill
44 Kern
46 Standard
47. Rice
48 Myers
49 Blue Mountain
50. Bucktown (Dillard)
52. Roberts and Peters
53 Keim
54. Empire
55. Custer
57. Ellis Owens
58. Owen Williams
59. Parry
60. Emerald
62. Old Franklin
63. Big Franklin
64 Provident and Hazel Dell
65 Peters
66 Fairview, East Carbon, Old Columbia, and nearby quarries
67. Williamstown
68 Hughes
70 East Berlin and nearby quarries
72. Penn Lynn
73 Blumont
74 New York Tunnel
75. Keim
76 Roth
77. Blue Valley
79. Eureka and Mountain
80 Pittston
81 Blue Diamond
82. Thomas and Roberts
83 Stels
87 Cambridge Shafts (Bachman Bros.) and Fairview Slate Co.'s Shaft
88 Blue Ridge
89 Old Cambridge and Pennsylvania-Star
91 Welshtown Tunnel and East End
92. Pullman and Keystone
94 Lehigh Gap and Bill Hughes
95 Lucerne
96 Riverside

Treichlers Group

99 Rockdale
100. Frantz
101. North Cementon
102. South Cementon
103. Reservoir
104 Roth

Walberts Group

105. Snyderville

Lowhill Group

106. West Claussville
107. East Claussville
108. Bachman
109. Flint Hill